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Radiation dosimetry in paediatric head CT examinations

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Introduction

- Pediatric dosimetry has unique characteristics: children have longer life expectancy and a much higher radiosensitivity due to their rapidly dividing cells

- In head Computed Tomography (CT), the lens of the eye is of great concern since recent studies support that the threshold for cataract formation is much lower than the previously considered dose level (2-5 Gy).

Introduction

- Paediatric patients are susceptible to radiation-induced risks due:
  - ✓ to their rapidly growing tissues
  - ✓ the wide and increased cellular distribution of skeletal active marrow
  - ✓ Their long post-exposure life expectancy

- In the literature there are limited data concerning radiation doses for paediatric head CT

Purpose

To present x-ray dosimetry measurements for paediatric head CT examinations performed in public hospitals in Athens.

Methods

We present a review of x-ray dosimetry results, measured and calculated by the Medical Physics Unit of 2nd Department of Radiology, School of Medicine, National and Kapodistrian University of Athens, from head CT examinations performed in public hospitals in Athens.

Methods: 1st Study ("in-vivo" measurements)

- **35 pediatric patients** who underwent head CT examinations on a 16-slice CT scanner in a dedicated children's hospital
- 3 age groups: 0-18 mo (group A), 18 mo-5 yr (group B) and 5-15 yr (group C) according to the Department's protocol
- Use of iterative reconstruction algorithm, axial mode and automatic exposure technique
- Gantry tilt was used in all scans to keep eyes outside the primary radiation beam. For each patient, 4 TLDs were placed on the center of both eyes

Methods: 2nd Study

- Included 3 hospitals: 2 paediatrics (PH1, PH2) and 1 general (GH1)
- **306 head CT examinations** from paediatric patients were retrospectively reviewed
- Age-adjusted scanning protocols
- Acquisition settings and dosimetric data were extracted from the DICOM header and recorded
- Effective dose (ED) calculated by utilizing age-specific DLP-to-ED k-conversion coefficients (ICRP 103 tissue weighting factors adopted)

Methods: 3rd Study

- **481 pediatric patients** who underwent head CT examinations on a 16-slice CT scanner in a dedicated children's hospital
- 3 age groups: 0-18 mo (group A), 18 mo-5 yr (group B) and 5-16 yr (group C) according to the Department's protocol
- Use of iterative reconstruction algorithm, axial mode and automatic exposure technique
- Gantry tilt was used in all scans to keep eyes outside the primary radiation beam.

Results: 1st study ("in-vivo" measurements)

	Eye lens dose (mGy)	Effective dose (mSv)
Group A	10.5±3.3	1.6±0.4
Group B	29.9±8.6	1.9±0.3
Group C	34.2±14.9	1.8±0.3

Results: 2nd study PH1

	Age groups			
	0-1	**1-5**	**5-10**	**10-15**
kVp	100.8±3.9	118.7±4.9	119.6±2.9	120.0±0.0
mean mA	176.6±38.4	179.7±53.3	240.5±53.2	259.7±69.6
Slice Thick. (mm)	2.5/5.0			
Mode	Axial			
CTDIvol (mGy)	28.3±9.9	50.2±20.0	54.7±23.6	69.4±32.0
DLP (mGy*cm)	411.3±142.7	743.9±307.7	819.9±405.8	1028.2±397.7

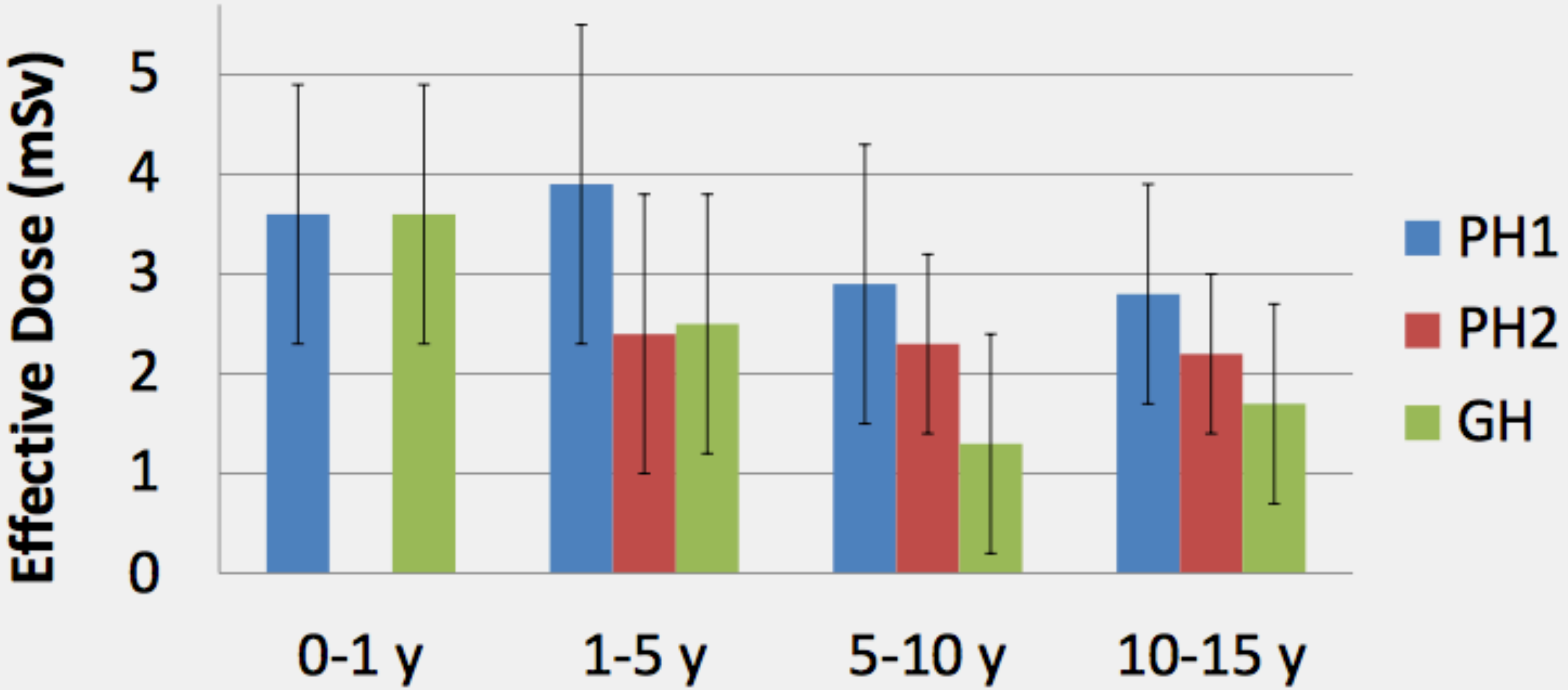
Results: 2nd study PH2

	Age groups			
	0-1	**1-5**	**5-10**	**10-15**
kVp	-	99.5±14.3	116.7±9.5	121.1±4.5
mean mA	-	404.5±117.0	389.1±74.0	394.5±62.9
Slice Thick. (mm)	-		3	
Mode	-		Axial & Spiral	
CTDIvol (mGy)	-	31.8±15.9	44.6±15.3	53.1±15.3
DLP (mGy*cm)	-	435.8±251.4	663.3±263.3	805.9±280.9

Results: 2nd study GH

	Age groups			
	0-1	1-5	5-10	10-15
kVp	120±0	103.3±13.7	103.3±15.3	110.0±14.1
mean mA	235.8±83.9	323.0±115.3	224.0±97.9	233.5±65.8
Slice Thick. (mm)	2.5			
Mode	Axial & Spiral			
CTDIvol (mGy)	23.9±10.8	31.3±18.4	29.5±20.3	47.3±28.6
DLP (mGy*cm)	419.1±149.2	456.3±237.7	367.6±235.6	615.2±371.8

Results: 2nd study – Effective dose



Results: 3rd study – Patient population

Age group	0-18 mo	18 mo-5 yr	5yr-16 yr
Clinical indication	Trauma, Tumor, Ventricles, Headache, Epilepsy		
No of examinations	81	99	301
Male/Female	52/29	53/31	185/116
Age (yr)	0.62±0.59	3.35±1.08	10.14± 2.86
Weight (kg)	8.80±8.48	15.73±5.34	40.18±15.77
Height (m)	0.70±0.20	1.00±0.15	1.43±0.19

Results: 3rd study – Acquisition parameters

Age group	0-18 mo	18 mo-5 yr	5yr-16 yr
Mode	axial	axial	axial
kVp	100	120	120
Slice Thickness (mm)	2.5/5	2.5/5	2.5/5
Rotation time (sec0	1	1	1
Noise index	8.80±8.48	15.73±5.34	40.18±15.77
Pitch	1	1	1

Results: 3rd study – Dosimetric parameters

Age group	0-18 mo	18 mo-5 yr	5yr-16 yr
DLP (mGy*cm)	356.7±163.8	578.4±185.5	765.6±256.1
Effective dose (mSv)	1.75±0.80	1.79±0.58	1.76±0.79

Discussion

- CT protocols varied in terms of acquisition parameters and scanning mode but effective doses were comparable among the various hospitals for the same age group

- Accurate patient's positioning and children's cooperation are important parameters for the reduction of eye lens dose.

Conclusion

In every hospital that treats paediatric patients it is necessary:

- Standardization of paediatric CT protocols. The European Guidelines on Diagnostic Reference Levels (DRLs) for Paediatric Imaging has proposed age-based protocols for head CT examinations and weight-based protocols for body CT examinations.
- Thorough optimization, use and revision of DRLs of CT protocols
- Continuous education and training on radiation protection aspects

Conclusion

- Establishment of a **Radiation Protection Culture in every Radiology Department**: *"The combination of knowledge, values, behaviors and experience of radiation protection (RP) in all its aspects for patients, workers, population and environment, and in all exposure situations, combining scientific and social dimensions"*.*

- Collaboration among physicians, medical physicists, nurses, and manufacturers.

*IRPA, Guiding Principles for Establishing a Radiation Protection Culture, Edition 2014

All the aforementioned (optimization, use and revision of DRLs, education) are highlighted in the new Basic Safety Standard Directive **2013/59** Euratom.

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II

(Non-legislative acts)

DIRECTIVES

COUNCIL DIRECTIVE 2013/59/EURATOM

of 5 December 2013

laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom

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