Radiation Dose Optimization Approach at Dubai Health Authority Hospitals:

The Control of Patient CT Radiation Exposures during 2008-2010

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Abstract

Introduction: A systematic approach in recording, observing and controlling CT doses were followed at Dubai Health Authority (DHA) radiology departments. In this paper, we are presenting the experience of Dubai Hospital in managing CT doses which resulted in a remarkable control of patient doses during a period of 3 years (2008-2010).

Method: Radiation doses generated from the 4MDCT Ge LightSpeed unit at Dubai Hospital are evaluated annually through the DHA Quality Control program. Dose measurements in terms of weighted CT Dose Index $CTDI_w$ (mGy) were frequently monitored using Head (16 cm diameter) and Body (32 cm diameter) ACR Accredited Cylindrical PMMA CT phantoms, Nero mAx 8000 meter and 10 cm pencil ion chamber.

Patient radiation doses in terms of Dose Length Product (DLP, mGy.cm) and volume CT Dose Index ($CTDI_{vol}$, mGy) along with patient and imaging parameters (Age, weight, kVp, mA, pitch, slice width, No. of slices, IQ, … ect) were manually recorded during 2008 for the common CT examinations: Head, Chest and Abdomen and Pelvis scans. In 2009-2010, these CT dose data were recorded within the Radiology Information System (RIS) and the Picture Archive and Communication System (PACS). CT Effective Doses (ED mSv) were also estimated in this work. Data accuracy verifications were followed and presented in this paper.

Results: The total number of adult patients undergone common CT examinations in this study was 6528 (558, 2617 and 3353 in 2008, 2009 and 2010, respectively) while pediatric group was 404 (55, 184 and 165 in 2008, 2009 & 2010, respectively). The doses results (DLP, $CTDI_{vol}$ and ED) in this study were analyzed as average and 3rd quartile for adult and pediatric patient groups and were compared to the initial Dose Reference Levels (DRLs) established for the DHA hospitals. The positive outcome of this radiation exposure study is manifested in the significant CT dose reduction for adult and pediatric patient groups with no noticeable drop in image quality. In compare to the local DRLs, adult doses were reduced by about 52%, 17.5% and 31% for head, chest and abdomen and pelvis examinations, respectively. For the pediatric group, the doses were reduced by about 46%, 38.6% and 48.6% for head, chest and abdomen and pelvis examinations, respectively. This has led to the introduction of new local DRLs. There were variations in the total number of patients for each common CT examination over the 3 years of this study. Hence, to avoid bias analysis, further investigations were considered.

Discussions and Conclusions: Radiation dose exposure control obtained in this study and technical actions to achieve it were discussed and found to be promising. Study limitations and future further considerations, such as the introduction of new local DRLs, were discussed in this paper. The RIS/PACS approach to record patient doses is effective and provides advantage of obtaining evidence on patient individual cumulative doses and population exposures.

Key words: CT Doses, CT Radiation Doses, Patient Radiation Doses, Control of Patient Radiation Doses, Control of Radiation Exposure. Dose Length Product (DLP), volume CT Dose Index ($CTDI_{vol}$) and Effective Doses (ED).

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1. Introduction and Background

The advantages of radiation in medical applications outweigh the risks. Although the risks from radiological procedures are considered small, professionals agree that exposure should be kept to the minimum without losing the image quality (hence, considering the ALARA principle of Radiation Safety; keeping the radiation exposure As Low As Reasonably Achievable). The spread of radiation practices, largely Radiology and Nuclear Medicine, contributed in increasing cancer occurrence among the population. Researchers anticipated that 2% of all solid cancer cases are attributed to medical exposure [1]. In order to minimize any potential risk, it is essential to control and optimize patient radiation doses. International and professional committees and organizations introduced recommendations, practices and programs to reduce patient exposures. Therefore, patient radiation safety is considered as an essential part of national and international radiation safety requirements.

The necessity to control radiation doses to patients motivated radiology and medical physics teams at Dubai Health Authority (DHA) to take part in the technical projects of the International Atomic Energy Agency (IAEA) to evaluate and monitor patient radiation doses. Since 2005, the UAE is participating in the IAEA patient protection regional project titled as: Strengthening Radiation Protection in Medicine (RAS9055; previously RAS9047). One of the aims of the project is to encourage the participating hospitals to establish Local Dose Reference Levels (DRLs) which ultimately will lead to establishing National DRLs.

During the past 5 years, the number of CT studies has doubled at the DHA hospitals. This situation, along with patients' overdoses and clinical radiation injuries reported internationally and the classification of CT as high-dose procedures by European Community [2] [3], has prompted actions within the DHA to establish a system to manage patient doses incurred due to medical imaging practices. A systematic approach in recording, observing and controlling CT doses were followed at the DHA radiology departments. At the DHA, we including patient dose recording and analysis as one of the key performance index (KPI) through our Joint Commission International (JCI) accreditation process. Hence, the concern departments (radiology and medical physics) considered, on monthly bases, reporting patient dose to the quality development departments within the hospitals. This administrative action helped to support our study to optimize patient doses and thus the dose survey was carried out systematically over 3 years (2008-2010). In this paper, we aim to demonstrate the dose optimization approach at Dubai Hospital (DH) and the technical steps taken to achieve it.

2. Material and Method

Radiation doses generated from the 4MDCT Ge LightSpeed unit at Dubai Hospital are evaluated annually through the DHA Quality Control program managed by the medical physics section. Dose measurements in terms of weighted CT Dose Index (CTDIw, mGy) were frequently monitored using Head (16 cm diameter) and Body (32 cm diameter) ACR Accredited Cylindrical PMMA CT phantoms, Nero mAx 8000 meter and 10 cm pencil ion chamber. Furthermore, all DHA imaging systems are checked through a periodic maintenance program which is supervised by the biomedical engineering section. Hence, the performance and image quality of the CT system were adequately observed thought the project. The DH radiologists also took part in reviewing the images during the dose optimization procedures to make sure that image quality level was well maintained.

Patient radiation doses in terms of Dose Length Product (DLP, mGy.cm) and volume CT Dose Index (CTDIvol, mGy) along with patient and imaging parameters (Age, weight, kVp, mA, pitch, slice width, No. of slices, IQ, … ect) were manually recorded during 2008 for the common CT examinations: Head, Chest and Abdomen and Pelvis scans. In 2009-2010, these CT dose data were recorded within the Radiology Information System (RIS) and the Picture Archive and Communication System (PACS). Through the PACS tracking system, it is mandatory for the CT operator to manually fill CT patient doses in the RIS in order to finish the patient tracking. All patients' dosimetry data were collected from the RIS and viewed as PACS Dose Report by Cogonos statistical software. The PACS Dose Reports were presented in PDF and Excel sheet formats. The PACS data were reviewed to exclude in-completed data. In order to verify the accuracy of the data, we compared the PACS CT Dose reports with the CT Dose reports generated by the CT system in image format through IMPAX software system. This process was done for data shown unacceptable values which was occurred either due to typing mistakes by the operators or due to image acquisition where combined studies reported as a single exam (such as the total was shown as Head DLP value where the actual data (checked through the IMPAX) show images of Head and Neck). In a number of cases,

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CT Dose Reports on IMPAX system were not available and thus the uncertain DLP data in the PACS report were excluded.

Estimating Effective Dose values provides a comparison base to compare doses from different diagnostic procedures and allows for a comparison of different imaging modalities [4] [5]. Effective doses (in mSv) for adult and pediatric patients were calculated for each body region (Head, Chest and Abdomen & Pelvis) by using the relationship:

$$\text{Effective Dose (E)} = \text{DPL (mGy. cm)} \ . \ k \qquad (1)$$

where k is empirical weighting factor (mSv . mGy-1 . cm-1). The k value is tabulated in the ICRP Report 102 for adult and pediatric groups.

3. Results:

The total number of adult patients undergone common CT examinations in this study was 6528 (558, 2617 and 3353 in 2008, 2009 and 2010, respectively) while pediatric group was 404 (55, 184 and 165 in 2008, 2009 & 2010, respectively). The doses results (DLP, $CTDI_{vol}$ and ED) in this study were analyzed as average and 3rd quartile for adult and pediatric patient groups and were compared to the initial Dose Reference Levels (DRLs) established for the DHA hospitals as shown in Tables 1-4 and in Figures 1-4. Although that the paediatric age at the DHA is defined as 13 years and below, for the purpose of this project the paediatric age was considered 15 years and below and were grouped based on the age as: 0- <1 year, >1-5 years, >5-10 years and >10-15 years. The results of these age groups are demonstrated in Figures 5-7. The findings in this study were compared to results published at the European regions [10] [11] [12].

Table -1: Average Dose Length Product for Adult Patients at DH.

	Adult Average (DLP, mGy cm)		
CT Examinations	**2008**	**2009**	**2010**
Abd + Pel	1059.033	723.430	690.404
Chest	493.464	384.730	412.654
Head	998.432	586.544	481.559

Table -2: Third Quartile values of Dose Length Product for Adult Patients group at DH.

	Adult 3rd Quartile (DLP, mGy cm)			
CT Examinations	**2008**	**2009**	**2010**	**DHA DRLs**
Abd + Pel	1167.875	851.020	763.428	1000
Chest	552.915	451.350	450.250	500
Head	1227.710	876.500	488.190	1000

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Figure – 1 Adult Average Dose Length Product (DLP) at DH, United Arab Emirates (UAE)

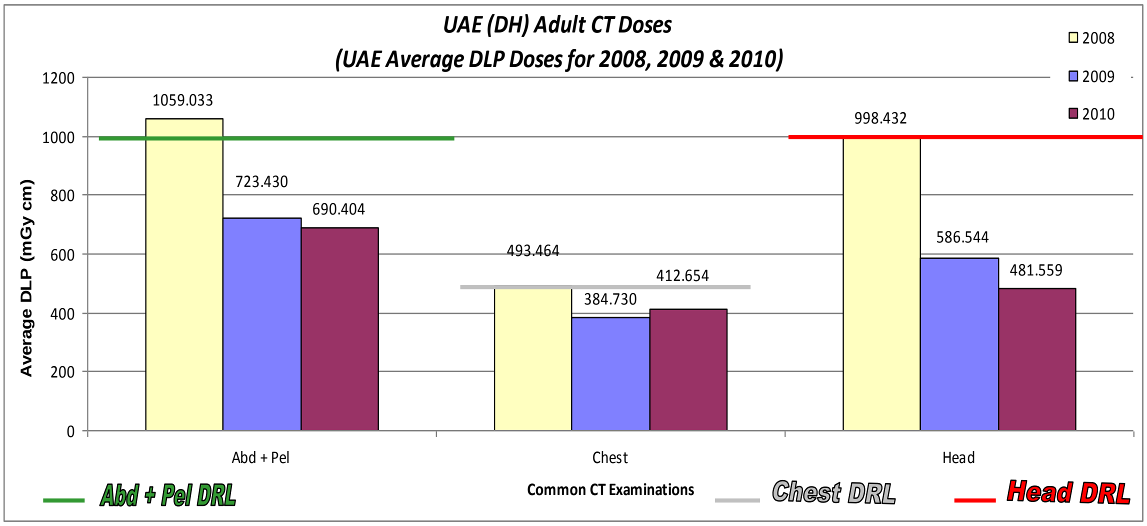

Figure – 2 Third quartile value of Dose Length Product (DLP) for adult patient group

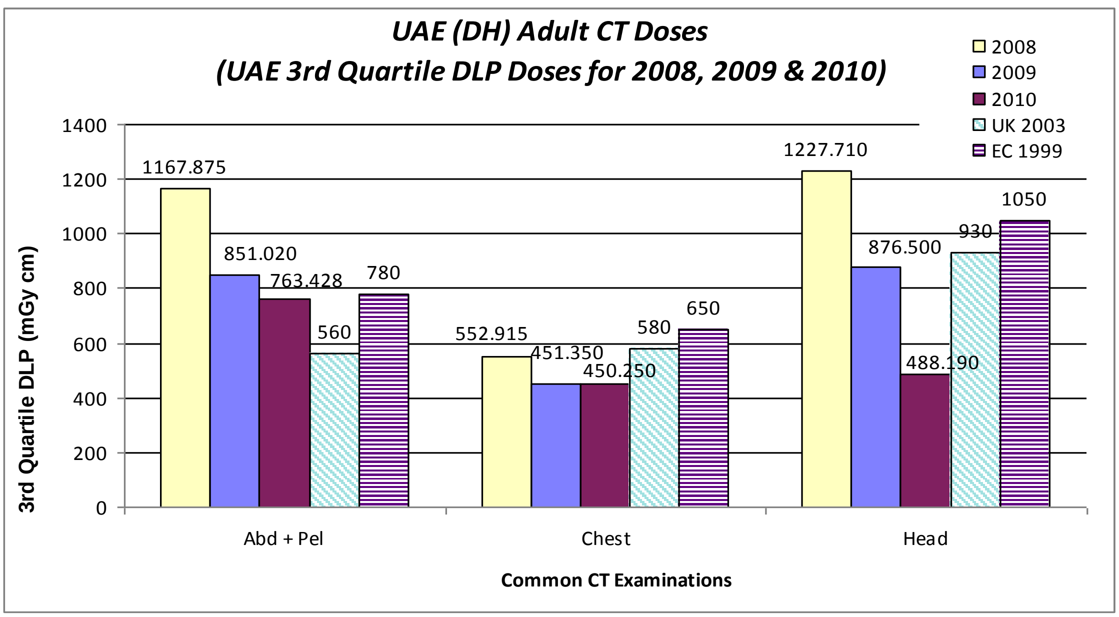

Table -3: Average DLP for Paediatric Patients (All age groups) at DH.

	Paediatric Average (DLP, mGy cm)		
CT Examinations	**2008**	**2009**	**2010**
Abd + Pel	453.569	351.940	309.456
Chest	305.037	192.394	180.792
Head	490.864	291.423	249.328

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Table -4: Third Quartile value of DLP for Paediatric Patients (All age groups) at DH.

	Paediatric 3rd Quartile (DLP, mGy cm)			
CT Examinations	**2008**	**2009**	**2010**	**DHA DRLs**
Abd + Pel	514.74	480	403.57	500
Chest	461.055	253	232.7075	300
Head	585.52	359.5	315	500

Figure – 3: Paediatric Average Dose Length Product (DLP) (All age groups)

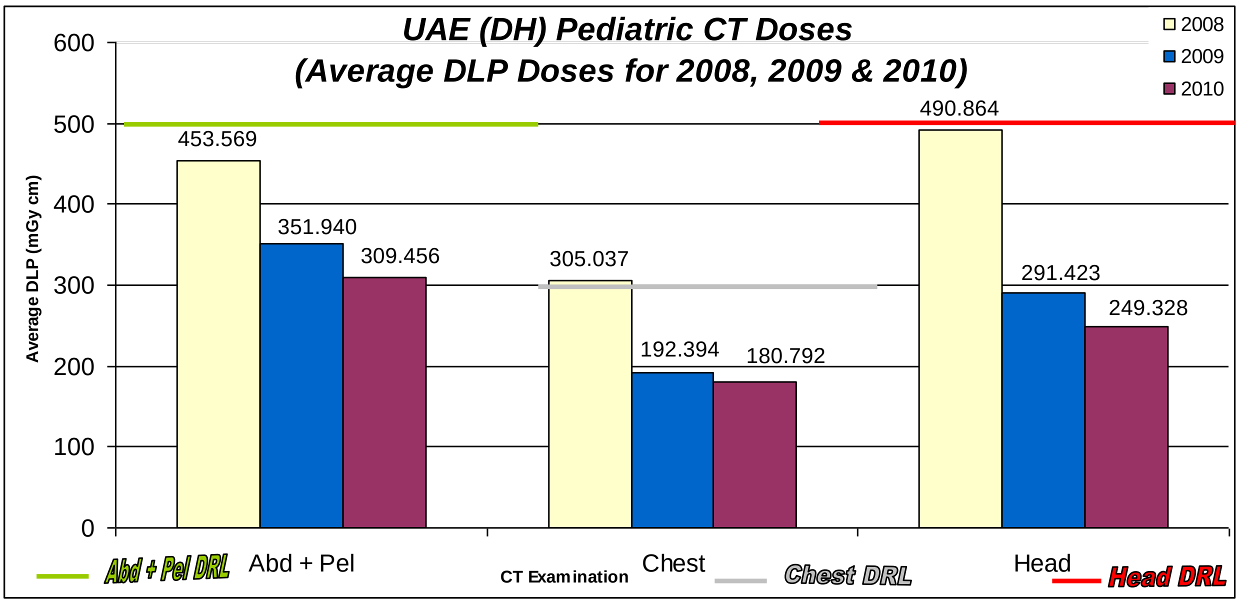

Figure -4: Third Quartile value of the Dose Length Product for Paediatric Patients (All age groups)

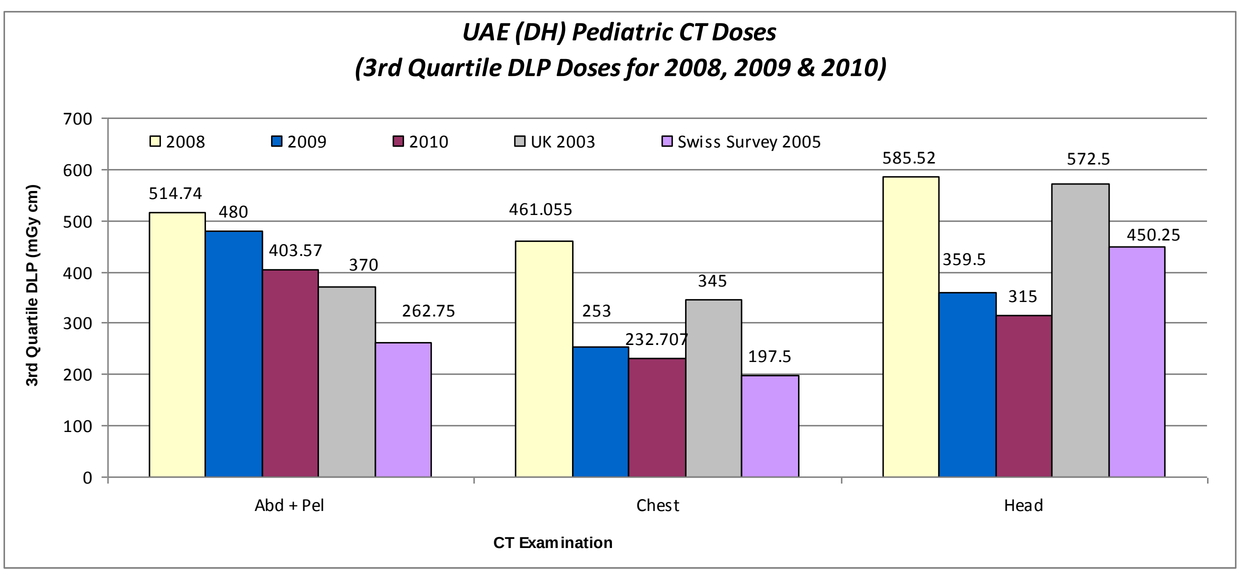

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Figure – 5: Paediatric Abdomen and Pelvis CT Doses (DLP) at DH

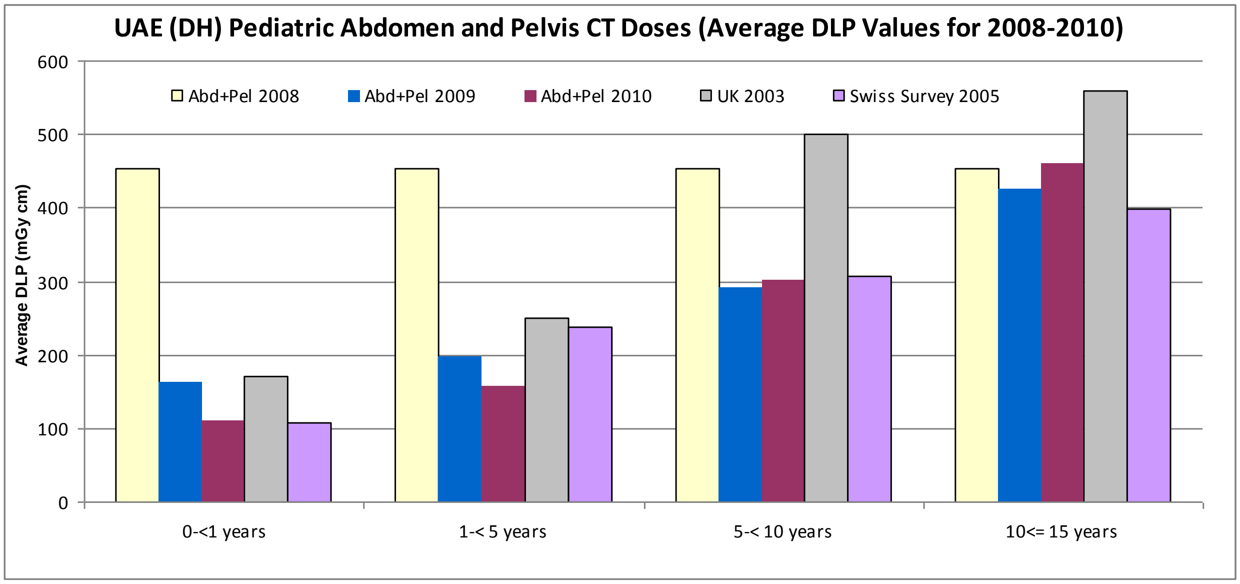

Figure – 6: Paediatric Chest CT Doses (DLP) at DH

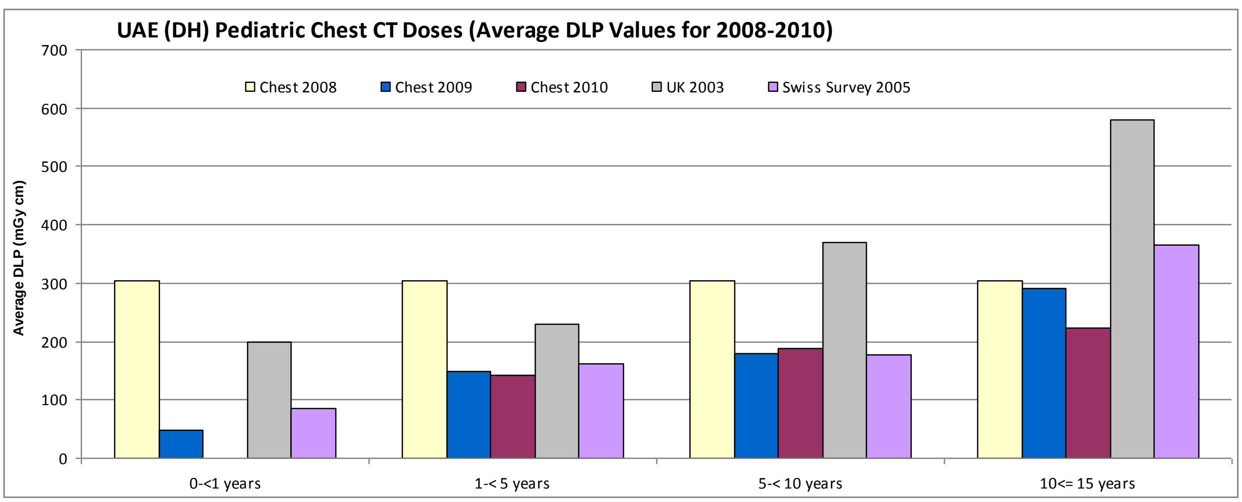

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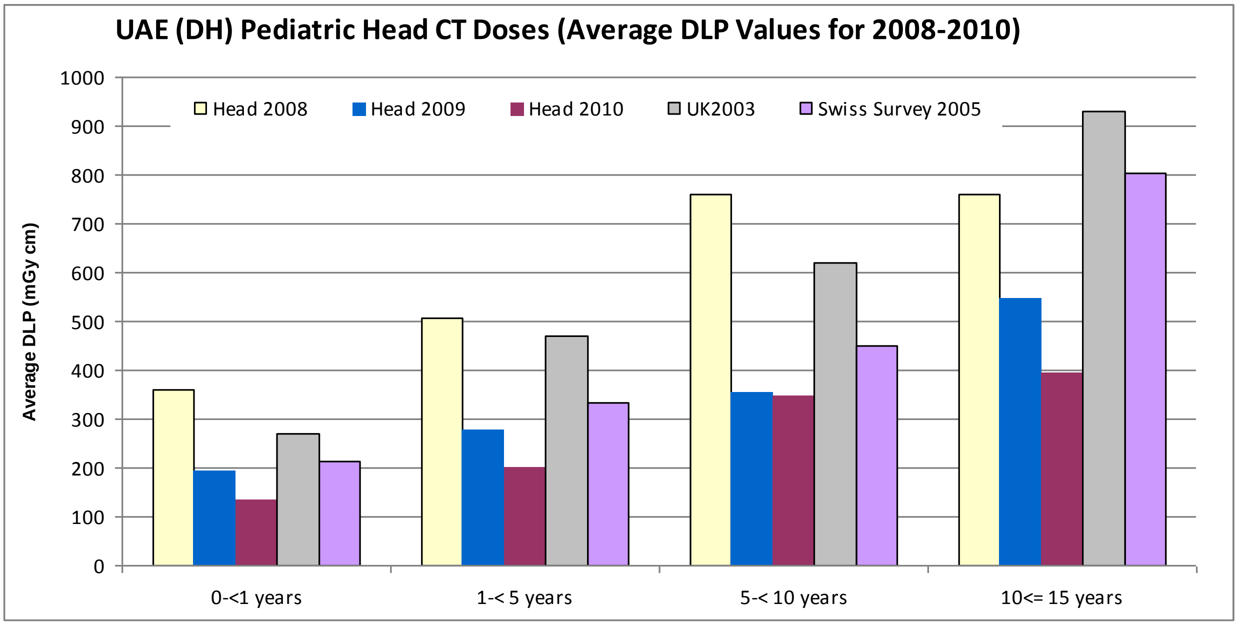
Figure – 7: Paediatric Head CT Doses (DLP) at DH



The positive outcome of this patient radiation exposure study is manifested in the significant CT dose reduction for adult and pediatric patient groups with no noticeable drop in image quality. In compare to the local DRLs, adult doses were reduced by about 52%, 17.5% and 31% for head, chest and abdomen and pelvis examinations, respectively. For the pediatric group, the doses were reduced by about 46%, 38.6% and 48.6% for head, chest and abdomen and pelvis examinations, respectively. CT effective doses for adult and paediatric groups were compared to the data published by the ICRP (Report 102) as survey carried out at the UK and other European Commission (EC) countries [5] [8] [9] [11]. The DHA results are presented in Tables 5 & 6.

Table – 5: Adult CT Effective Doses at DH for years 2009 & 2010.

Adult CT Exam		2009*	2010	Reference (1/2).**
		CT Effective Dose (mSv)		
Head	Average	1.23	1.011	2.8 / 2.0
	SD	0.58	0.399	
	3rd Quartile	1.84	1.025	
Chest	Average	5.39	5.777	5.7 / 8
	SD	1.63	2.560	
	3rd Quartile	5.52	6.304	
Abd+Pel	Average	10.85	15.271	14.4 / 10
	SD	4.27	2.872	
	3rd Quartile	10.33965	15.920	

** DHA published data [7]*

*** ICRP (MDCT, 2007 Rep 102), 1 - Brix et al. (2003)[8]; 2 - RCR (2003) [9].*

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Table – 6: Paediatric CT Effective Doses at DH for years 2009 & 2010.

		2009*				2010			
		0-<1y	1-<5y	5-<10y	10-<=15y	0-<1y	1-<5y	5-<10y	10-<=15y
Paed.CT Exam		**Effective Dose (mSv)**							
Head	**Average**	2.15	1.95	1.41	1.69	1.47	1.36	1.39	1.26
	SD	1.86	1.28	1.01	1.03	0.62	0.67	0.74	0.68
	3rd Quartile	2.43	2.38	1.47	2.6	1.72	1.74	1.95	1.44
Reference***		3.00	1.90	2.00	_	3.00	1.90	2.00	_
Chest	**Average**	1.87	3.55	3.23	3.47		3.68	3.39	2.90
	SD	0.31	0.52	1.27	1.72		4.02	1.74	0.64
	3rd Quartile	1.97	3.79	2.96	4.45		2.78	3.93	3.17
Reference***		7.90	4.10	4.80	_	3.00	1.90	2.00	_
Abd+Pel	**Average**	7.95	5.15	5.84	5.75	5.40	4.71	6.01	6.90
	SD	4.6	2.32	3.09	2.65	1.08	1.67	3.44	3.17
	3rd Quartile	9.75	6.36	6.42	7.31	6.15	5.21	8.10	7.95

** DHA published data [7]*

**** UK Survey 2003 , BJR 79 (2006), 968-980 [11]*

4. Discussions and Conclusions:

In this study, the radiology and medical physics teams constantly observed the CT radiation Dose levels and technical actions were taken to optimize patient doses. These techniques included introducing the use of automatic dose modulation which is based on patients' body size and paediatric low-dose protocols were used through the modification and utilization of the manufacture protocols specifically designed for children. Furthermore, the team accepted some increase in the noise index while, at the same time, continuously checked the image quality. Moreover, the length of body that included in the image was kept to the minimum as it is needed to obtain adequate clinical information. Actions to decrease the kVp and increase the gantry rotation speed were independently taken for selected exams. As a result of this study, the use of bismuth shielding was introduced within the CT imaging practices at the DHA. The dose reduction obtained in this study encouraged the DHA team to lower the DHA DRLs where paediatric patient age groups were taken into considerations. Since the DH were in the process to replace the old 4MDCT Ge LightSpeed system with a new CT system, the introduction of new DHA DRLs were not fully implemented and a plan of reviewing the adult and paediatric doses for the new system will be conducted before considering the changes in the current local DRLs.

Radiation dose exposure control obtained in this study found to be promising. The DHA CT DLP dose levels were comparable to those reported by European countries. For adult group, the abdomen and pelvis CT doses were slightly higher while those for chest and head examinations were lower than the EC countries' data. For paediatric group, the doses were, in general, lower than those reported by the EC regions with slight increase of the abdomen and pelvis data which where averaged among all the paediatric age groups. The CT effective doses are considered as a limiting dose indicator and not as an absolute; however it is useful to compare different protocols or imaging techniques. The DHA effective data were within the same range as those of the EC regions, and also demonstrated the same trends among the different CT examinations. There were variations in the total number of patients for each common CT examination over the 3 years of this study; the total number of patients for 2008 was not confidently comparable to 2009 & 2008. Hence, we did not consider the estimation of effective doses for the patients in year 2008.

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The RIS/PACS approach to record patient doses is effective and provides advantage of obtaining evidence on patient individual cumulative doses and population exposures. Furthermore, PACS dose reporting may be utilized as a tool to facilitate dosimetry clinical auditing. As a result of this study, we utilized the PACS technology to record and monitor patient dosimetry for CT examinations at other hospitals of the DHA and also for other radiology diagnostic procedures.

Acknowledgement

The authors of this paper are profoundly acknowledging and thanking the radiologists and radiographers teams at Dubai hospital and at the other DHA hospitals for their important cooperation in this study. The authors are thanking and appreciating the medical physics team at Dubai Hospital and the previous members of the project, namely, Abderrachid Zitouni; Sara Mohamed BuHumaid; and Syed Asim Gilani for their valuable contribution. A special thanks and appreciations are to Ms Noora Sultan Hamad Al Shibli for her excellent efforts in producing PACS CT Dose reports. The ultimate appreciations are extended to the IAEA, namely M. Rehani, IAEA Technical Officer, for the support and guidance in executing this project.

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