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PAEDIATRIC CT OPTIMISATION UTILISING CATPHAN® 600 AND AGE-SPECIFIC ANTHROPOMORPHIC PHANTOMS

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The purpose of the study is to perform phantom-based optimisation of paediatric computed tomography (CT) protocols and quantify the impact upon radiation dose and image noise levels. The study involved three Portuguese paediatric centres. Currently employed scanning protocols for head and chest examinations and combinations of exposure parameters were applied to a Catphan® 600 phantom to review the CT dose impact. Contrast–noise ratio (CNR) was quantified using Radia Diagnostic® tool. Imaging parameters, returning similar CNRs (<1) and dose savings were applied to three paediatric anthropomorphic phantoms. OsiriX software based on standard deviation pixel values facilitated image noise analysis. Currently employed protocols and age categorisation varied between centres. Manipulation of exposure parameters facilitated mean dose reductions of 33 and 28 % for paediatric head and chest CT examinations, respectively. The majority of the optimised CT examinations resulted in image noise similar to currently employed protocols. Dose reductions of up to 33 % were achieved with image quality maintained.

INTRODUCTION

As with all medical procedures, computed tomography (CT) examinations present both clinical benefits and potential radiation risks. In the past 10 y, the employment of CT examinations for paediatric patients increased ~700 % worldwide and increasingly being the preferred method in daily practice and emergency departments[1, 2]. The clinical applicability of CT for paediatric diagnosis is unquestionable; however, the potential risk of high radiation exposure associated with CT should not be ignored[3]. Recent studies have suggested that CT examinations in children can deliver examination doses of ~50–60 mGy that might almost triple the risk of leukaemia or brain cancer, respectively[4, 5].

The clinical benefits of prescribed examinations should outweigh the risks[4, 6]. Justification of all CT examinations is a legislative requirement; however, recent studies have indicated that many paediatric CT scans are unnecessary[7–9]. Optimisation of practice is essential to ensure the minimisation of radiation dose to the patient whilst ensuring diagnostic efficacy is maintained[10]. Several studies have reported that optimisation processes need to consider numerous factors including body region, clinical information, the CT scanner technology available and image processing[8, 11–14]. The Image Gently campaign clearly states that 'Children are not just smaller adults, their bodies are different and require a different approach to imaging'. Paediatric CT protocols should be defined by patient size taking into account their high radiosensitivity and longer lifetime expectancy[15–17].

Multi-slice CT (MSCT) technology evolution over the last decade increased the CT image quality by allowing the use of finer slice thicknesses and decreased the examination time[18]. However, to maintain acceptable noise when using finer slice thickness settings, patient doses must be increased[19]. The dose levels in CT examinations are determined by CT scanner technology and by exposure parameter selection[20]. The number of detectors, beam shape and filtration, the data acquisition system and the tube current modulation are the principal differences between CT manufacturers[21]. A thorough understanding of CT scanner design characteristics is essential to aid optimisation of practice[15].

Several research studies have focused upon optimisation in paediatric CT. Nievelstein *et al.*[10] indicated a number of strategies for paediatric CT dose reduction, for example: selective organ shielding, minimising the

number of examination phases and exposure parameter changes, to include increased pitch values, appropriate tube voltage selection and automatic tube current modulation. Strauss *et al.*[15] defined ten steps to optimise paediatric CT dose beyond the indications for tube voltage, tube current and pitch already outlined. These included: centring the patent in the middle of the gantry, reducing the dose during scout views, selecting the acquisition mode according to the body region and reducing the detector size in z direction. Lifeng Yu *et al.*[14] analysed tube current and tube voltage techniques in phantoms and patients to reduce paediatric CT dose and reported that the use of lower tube potential should be carefully selected according to patient sizes and the diagnosis task being performed. Other authors[8] have presented the impact of exposure parameter manipulation and image processing in chest and abdominal paediatric CT examinations, identifying potential reductions in dose of up to 30 % and the management of noise levels through post-processing techniques.

The majority of CT scanners use automatic exposure control based on tube current modulation. Iterative reconstruction and the adjustment of tube voltage based on patient size are the most recent and promising technologies for optimisation in CT; however, these are not widely available[11, 22, 23]. Reductions in tube voltage and current will result in lower CT dose levels; however, this in turn impacts upon the contrast–noise ratio (CNR) and the balance of the amount of noise present in resultant image. Therefore, image quality consideration is required to ensure whether diagnostic quality is not lost and radiology confidence is maintained[9, 24, 25].

This study is focussed upon head and chest CT examinations being the most common paediatric CT examinations across Europe[26–30]. It has also been noted that dose optimisation has higher relevance on population effective dose levels if applied on most common CT procedures[31].

The aim of this research was to investigate methods of optimisation for paediatric head and chest examinations following review of the CT protocols currently employed in the three national paediatric centres in Portugal. Optimisation was based on the manipulation of exposure parameters applied to anthropomorphic paediatric phantoms and included image noise evaluation based on standard deviation measurements within defined homogenous regions of interest (ROIs) following initial experimental testing on a Catphan® 600 phantom.

MATERIALS AND METHODS

Optimisation tests were carried out in the three dedicated regional, public paediatric centres, in Portugal (A, B and C), each performing ~3000 CT examinations annually. All 3 centres have MSCT models, 2 manufactured by Siemens™ (64 multidetector rows and 6 multidetector rows) and 1 by Philips™ (16 multidetector rows). CT protocols were collected from each centre and reviewed.

The CT Dose Index (CTDIvol—mGy) of the three CT scanners was verified using a calibrated Raysafe™ Xi CT ionisation chamber and a PMMA (Polymethyl methacrylate) CTDI phantom. The Statistical Package for Social Sciences (SPSS—version 20) software was employed to complete descriptive statistical analysis of the data collected. Three separate phases of experimental work formed the research.

Phase 1: optimisation using Catphan® 600

A Catphan® 600 (The Phantom Laboratory, Salem, USA) CT quality assurance (QA) phantom (Figure 1) was employed to optimise the existing protocols. The Catphan® 600 is internationally recognised as CT QA phantom, for use in axial, spiral and multi-slice CT scanners. This phantom is constructed by solid cast material modules (Figure 2) suitable for testing low contrast with supra-slice and sub-slice contrast targets (module CTP 515)[32]. The existing protocols were applied in alignment with paediatric age categories used internationally[26–29]: these being: newborns, 5- and 10-y-old children.

Head and chest CT protocols were used to scan the Catphan®600 in the three paediatric centres, exposure

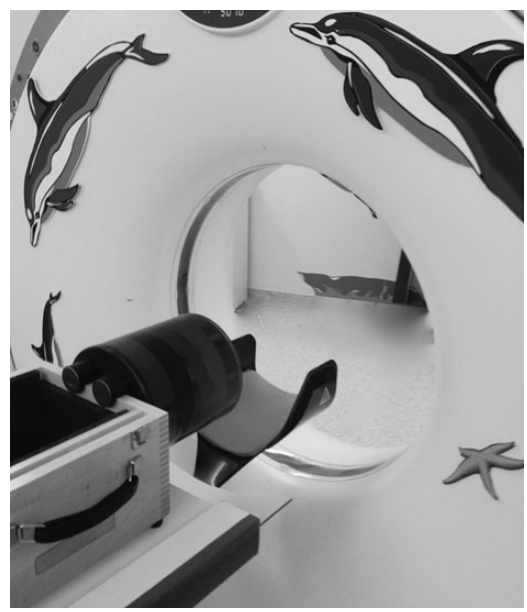

Figure 1. CT quality assurance phantom, Catphan ® 600, positioning to test head and chest paediatric CT examinations.

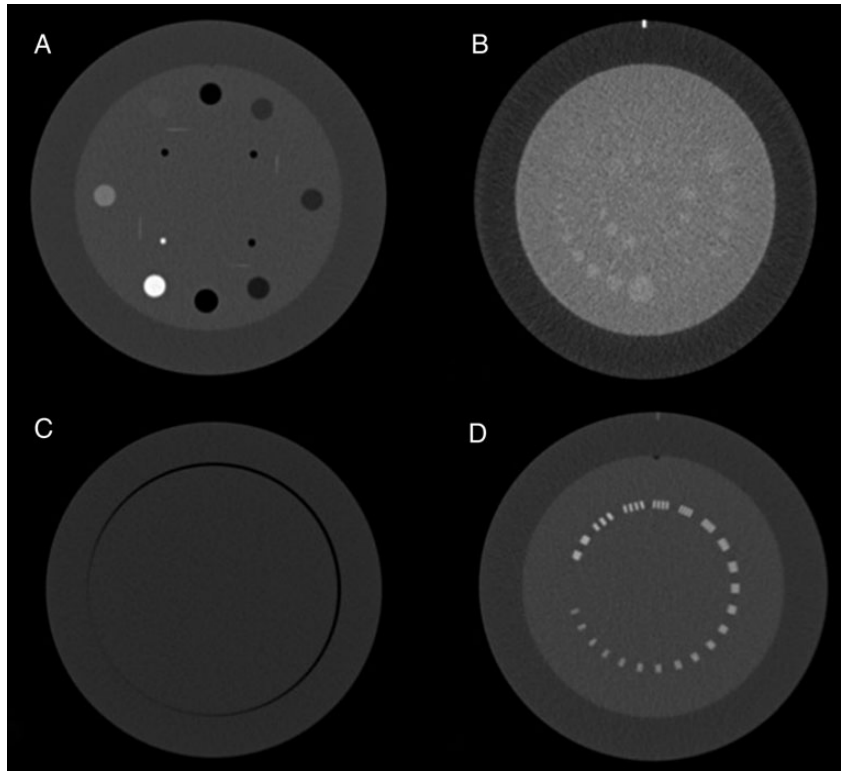

Figure 2. CT images of Catphan ® 600 modules. (**A**) CTP 404, (**B**) CTP 515, (**C**) CTP 486, (**D**) CTP 591.

parameters were systematically lowered from currently employed parameters: tube voltage, tube current and slice thickness were decreased and pitch was increased; acquisition mode and dose modulation based on tube current was also tested. The scanned length remained constant (20 cm), and CT scanner dose reports were used to obtain $CTDI_{vol}$ per head and chest CT examination.

Phase 2: image quality evaluation with Radia Diagnostic® software

The Catphan® 600 images generated were evaluated by Radia Diagnostic® Imaging QC software from Radiological Imaging Technology (RIT), Inc., CO, USA. This software scores images per American College of Radiology guidelines and generates analysis reports per module with measures, plots (Figure 3) material values and CT number linearity[33]. The CNR results, of module CTP 515 of the Catphan® 600, was the parameter considered for image evaluation as noise is the principal limiting factor in CT image quality and is directly influenced by radiation dose.

Phase 3: optimisation with age-specific anthropomorphic phantoms

Following review of the dose and image noise findings obtained with the Catphan® 600, the experimental protocols, according to scanner type, were defined and applied to head and chest CT examinations using CIRS® anthropomorphic phantoms (ATOM dosimetry verification phantoms—model 703, 705 and 706), which simulate 0- (3.5 kg, 51 cm), 5- (19 kg, 110 cm) and 10- (32 kg, 140 cm) y-old children (Figure 4), respectively. CTDIvol findings were recorded from the CT scanner dose reports. DLP values were not considered for the anthropomorphic phantoms (APs) due to the consistency of range length used.

Phase 4: anthropomorphic image quality evaluation with OsiriX® software

Anthropomorphic images were analysed using OsiriX® Imaging software (Antoine Rosset, Geneva) version 4.0 32 bit, using the standard deviation of 1 cm^2 homogenous ROIs. For head CT examinations, ROIs were established in the supra-tentorial region,

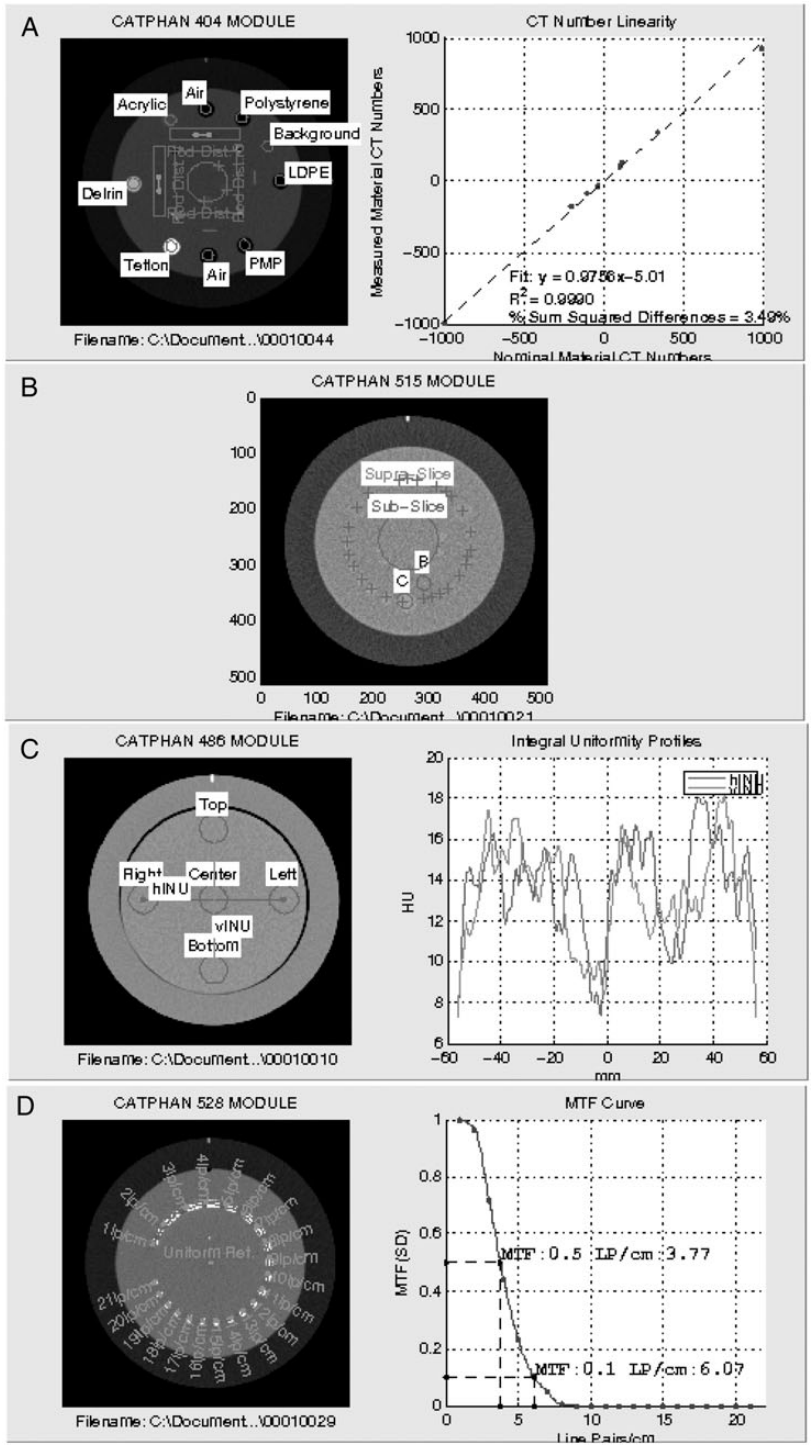

Figure 3. Example of RIT's Radia Diagnostic® software reports of the four different Catphan® 600 modules. (**A**) CTP 404, (**B**) CTP 515, (**C**) CTP 486, (**D**) CTP 591.

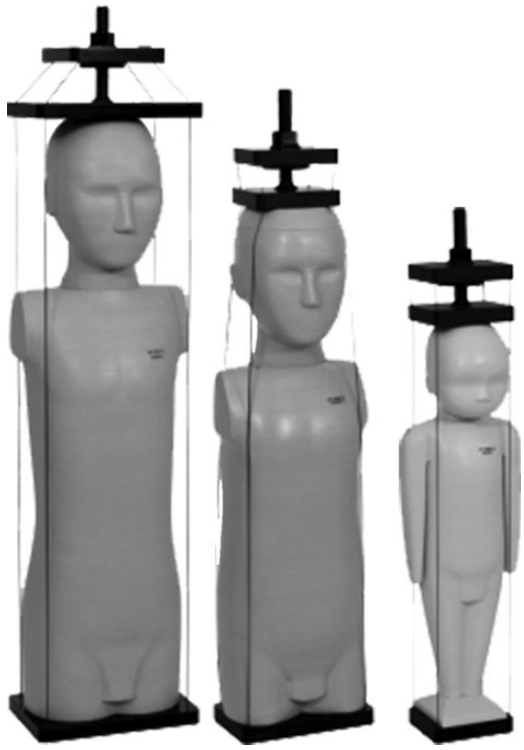

Figure 4. CIRS® Anthropomorphic phantoms (ATOM Model 706, 705 and 703) used to perform head and chest paediatric CT examinations.

orbits and infra-tentorial region, and for chest CT, the ROIs were positioned at points in the region of the shoulder and heart (Figure 5). A total of 9 ROIs were defined for head CT examinations and 6 ROIs for chest, totalling 465 ROIs.

RESULTS

Phase 1: optimisation using Catphan® 600

A total of 99 CT examinations were performed on the Catphan® 600 phantom involving the application of experimental head and chest imaging protocols; these were tailored to the scanner model: Centre A (n=38), Centre B (n=30) and Centre C (n=31).

For head CT examinations, Centre A reported two currently employed protocols (0- to 3-y-olds and >3-y-olds), Centre B identified three protocols (newborns, 1-y-olds and 2- to 10-y-olds) and Centre C using three different categories (0- to 18-month-olds, 18-month- to 6-y-olds and >7-y-olds). For chest CT examinations, the currently employed protocol categorisation is the same as outlined for head examinations except for Centre C, which had one currently employed protocol, and reported that this was adjusted in practice to individual patients.

Phase 2: image quality evaluation with Radia Diagnostic® software

Following a review of the Catphan® 600 findings, the selection of protocols to be applied to the APs was limited to a variation of 1.3 in CNR, when compared with the currently employed. The protocols were divided per age categorisation, in order to be performed on age-specific APs.

Phase 3: optimisation with age-specific APs

A total of 61 CT examinations were performed to test the impact of exposure parameter manipulation from the currently employed values, for the three scanner models. The CNR findings obtained by the Radia Diagnostic® software and the resulting dose values from the 0-, 5- and 10-y-old APs (AP) for the three paediatric centres are presented in Tables 1–3.

In comparison with the currently employed protocol, the overall mean percentage dose reduction achieved was 42, 31 and 25 % for head CT examinations and 38, 39 and 6 % for chest CT examinations, respectively, for 0-, 5- and 10-y-old APs.

The mean dose reduction per paediatric centre was 36, 25 and 32 % for head CT examinations and 9, 29 and 40 % for chest CT examinations, respectively, for Centres A, B and C in comparison with the currently employed protocol.

Phase 4: anthropomorphic image quality evaluation with OsiriX® software

The results of the ROI standard deviation and $CTDI_{vol}$ reduction analysis are summarised in Tables 4 and 5.

The majority of the optimised CT protocols, across the three paediatric centres resulted in reduced image noise when compared with the currently employed protocols, returning a mean pixel value standard deviation of 10 ± 6.4. In comparison with the currently employed parameters for head CT examinations, the highest variation in mean pixel value standard deviation of the experimental protocols were 35, 13 and 58 % for Centres A, B and C, respectively. The highest variation in mean pixel value standard deviation recorded for chest examinations were 8, 54 and 36 % for Centres A, B and C, respectively.

DISCUSSION

Phase 1: optimisation using Catphan® 600

The variation in CT equipment across the three centres determined the need to tailor optimisation to equipment models[25].

A number of exposure parameters impeded the ability to standardise across the centres, these included: variation in tube voltage selection and tube current dose modulation options, slice thickness combinations

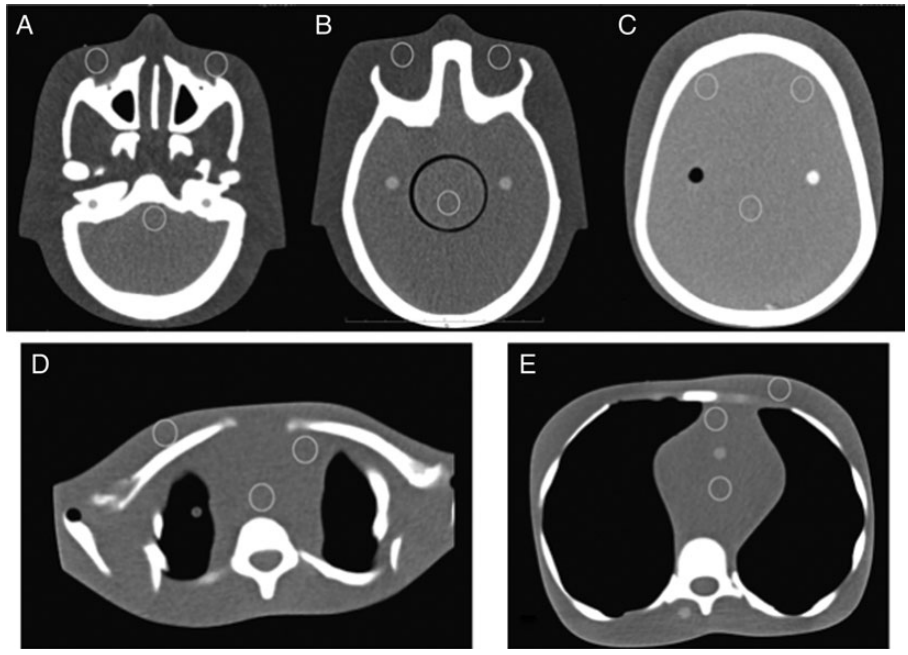

Figure 5. Example of ROI locations, for image analyses with OsiriX® software, for head (**A**–**C**) and chest (**D** and **E**) CT examinations on the AP (Model 705).

Table 1. A summary of CNR findings using the RIT's Radia Diagnostic® software and the CT dose values (CTDIvol) of the currently employed and experimental protocols for head and chest paediatric CT examinations performed on APs in Centre A.

Body Region	*n*°	Tube voltage (kV)	Rotation time (s)	Tube current–time product (mAs)	Slice thickness (mm)	Mode	Pitch	Tube current modulation	CNR	AP	CTDI (mGy)
Head	1[a]	120	1	230	4.8	A	—	No	2.51	0	38.25
	2	120	1	200	4.8	A	—	No	2.39	0	33.41
	3	100	1	230	4.8	A	—	No	1.63	0	23.46
	4	80	1	260	4.8	A	—	No	1.50	0	13.42
	5[a]	120	1	310/290	2.4/4.8	A	—	No	1.38	5	49.95
	6	100	1	310/290	2.4/4.8	A	—	No	1.81	5	30.64
	7	100	1	250	2.4/4.8	A	—	No	2.01	5	25.51
	8	120	1	310/290	2.4/4.8	A	—	No	1.38	10	41.57
	9	100	1	310/290	2.4/4.8	A	—	No	1.81	10	25.03
	10	100	1	250	2.4/4.8	A	—	No	2.01	10	20.82
Chest	11[a]	80	0.5	50	5	H	0.8	No	0.77	0	0.81
	12	80	0.5	50	5	H	0.8	Yes	0.72	0	0.65
	13	80	0.5	40	5	H	0.9	No	2.50	0	0.68
	14[a]	100	0.5	50	5	H	0.8	No	1.46	5	1.76
	15	100	0.5	40	5	H	0.8	No	1.09	5	1.41
	16	100	0.5	50	5	H	0.9	No	1.17	5	1.76
	17	100	0.5	50	5	H	0.8	Yes	1.46	10	1.97
	18	100	0.5	50	5	H	0.8	No	1.09	10	2.22
	19	100	0.5	50	5	H	0.9	No	1.17	10	2.22

[a]CT currently employed protocol.

Table 2. A summary of CNR findings using the RIT's Radia Diagnostic® software and the CT dose values (CTDIvol) of the currently employed and experimental protocols for head and chest paediatric CT examinations performed on APs in centre B.

Body Region	n°	Tube voltage (kV)	Rotation time (s)	Tube current–time product (mAs)	Slice thickness (mm)	Mode	Pitch	Tube current modulation	CNR	AP	CTDI (mGy)
Head	1[a]	80	2.5	200/130	5	A	—	Yes	1.74	0	6.04
	2	80	2.5	180	5	A	—	No	1.49	0	10.98
	3	80	2.5	130	5	A	—	No	1.51	0	7.93
	4	80	2.5	180	5	H	0.9	Yes	1.71	0	10.98
	5[a]	130	2.5	140	4	A	—	No	2.42	5	33.04
	6	110	2.5	140	4	A	—	No	2.14	5	22.82
	7	110	2.5	130/183	4	H	0.9	Yes	2.49	5	32.20
	8	110	2.5	130	4	H	0.9	No	2.33	5	24.70
	9	130	2.5	140	4	A	—	No	2.42	10	30.50
	10	110	2.5	140	4	A	—	No	2.14	10	21.06
Chest	11[a]	110	0.8	40	5	H	1.5	Yes	1.33	0	1.90
	12	110	0.8	40	5	H	1.5	No	1.18	0	3.48
	13	80	0.8	40	5	H	1.5	Yes	0.89	0	0.93
	14	80	0.8	40	5	H	1.5	No	1.58	0	1.40
	15[a]	110	0.8	80	5	H	1.5	Yes	1.00	5	7.62
	16	110	0.8	80	5	H	1.5	No	1.44	5	6.98
	17	110	0.8	50	5	H	1.5	Yes	1.53	5	3.94
	18	110	0.8	50	5	H	1.5	No	1.23	5	4.36
	19[a]	110	0.8	80	5	H	1.5	Yes	1.00	10	2.64
	20	110	0.8	80	5	H	1.5	No	1.44	10	6.00
	21	110	0.8	50	5	H	1.5	Yes	1.53	10	2.64
	22	110	0.8	50	5	H	1.5	No	1.23	10	3.76

[a]CT currently employed protocol.

Table 3. A summary of CNR findings using the RIT's Radia Diagnostic® software and the CT dose values (CTDIvol) of the currently employed and experimental protocols for head and chest paediatric CT examinations performed on APs in Centre C.

Body Region	n°	Tube voltage (kV)	Rotation time (s)	Tube current–time product (mAs)	Slice thickness (mm)	Mode	Pitch	Tube current modulation	CNR	AP	CTDI (mGy)
Head	1[a]	120	0.75	300	3	A	—	No	2.42	0	45.60
	2	90	0.75	300	3	A	—	No	2.15	0	21.10
	3	120	0.75	250	3	A	—	No	1.51	0	38.00
	4	90	0.75	230	3	A	—	No	1.96	0	16.20
	5	120	1	300	3	A	—	No	1.23	5	44.90
	6[a]	120	0.75	350	3	A	—	No	2.45	5	52.40
	7	120	0.75	250	3	A	—	No	3.49	5	37.40
	8	90	0.75	250	3	A	—	No	2.20	5	17.50
	9	120	0.75	375/300	3/6	A	—	No	2.45	10	42.75
	10	120	0.75	350/250	3/6	A	—	No	2.20	10	36.55
Chest	11[a]	120	0.5	50	3	H	0.688	No	0.56	0	3.50
	12	90	0.5	50	3	H	0.688	No	0.59	0	1.50
	13	90	0.5	50	3	H	1	No	0.51	0	1.50
	14	90	0.5	50	5	H	1	No	0.54	0	1.50
	15[a]	120	0.5	50	3	H	0.688	No	0.56	5	3.50
	16	90	0.5	50	3	H	0.688	No	0.59	5	1.50
	17	90	0.5	50	3	H	1	No	0.51	5	1.50
	18[a]	120	0.5	50	3	H	0.688	No	0.56	10	3.70
	19	120	0.5	50	5	H	0.688	No	0.37	10	3.30
	20	120	0.5	50	3	H	1	No	0.55	10	3.70

[a]CT currently employed protocol.

Table 4. Percentage of dose reduction (CTDIvol) and ROI's mean and percentage standard deviation for head CT protocols, per paediatric APs, analysed by individual centres, in comparison with currently employed protocols.

AP	Centre A				Centre B				Centre C			
	Protocol number	SD mean	% CTDIvol	% SD	*N*°	SD mean	% CTDIvol	% SD	*N*°	SD mean	% CTDIvol	% SD
0	1[a]	3.85	NA	NA	1[a]	24.31	NA	NA	1[a]	12.89	NA	NA
	2	3.47	−13	−10	2	24.06	31	−1	2	3.54	−54	−73
	3	3.39	−39	−12	3	24.04	82	−1	3	2.74	−17	−79
	4	2.96	−65	3	4	26.56	82	9	4	3.82	−64	−70
5	5[a]	3.51	NA	NA	5[a]	5.67	NA	NA	5	3.42	−14	28
	6	4.51	−39	29	6	6.41	−3	13	6[a]	2.68	NA	NA
	7	4.72	−49	35	7	5.90	−25	4	7	3.44	−17	29
					8	6.20	−31	9	8	4.85	−61	44
10	8[a]	5.01	NA	NA	9	4.64	NA	NA	9	3.55	NA	NA
	9	6.00	−40	20	10	5.20	−31	12	10	3.55	−19	58
	10	6.77	−50	35								

[a]CT currently employed protocol.

Table 5. Percentage of dose reduction (CTDIvol) and ROI's mean and percentage standard deviation for chest CT protocols, per paediatric APs, analysed by individual centres, in comparison with currently employed protocols.

AP	Centre A				Centre B				Centre C			
	Protocol number	SD mean	% CTDIvol	% SD	*N*°	SD mean	% CTDIvol	% SD	*N*°	SD mean	% CTDIvol	% SD
0	11[a]	12.77	NA	NA	11[a]	10.68	NA	NA	11[a]	10.61	NA	NA
	12	12.39	−20	−3	12	10.08	83	−6	12	14.30	−57	35
	13	12.53	−16	−2	13	12.94	−51	21	13	14.41	−57	36
					14	10.91	−26	2	14	12.22	−57	15
5	14[a]	7.95	NA	NA	15[a]	5.05	NA	NA	15[a]	20.58	NA	NA
	15	8.62	−20	8	16	5.65	−8	12	16	18.07	−57	−12
	16	7.54	0	−5	17	7.78	−48	54	17	18.82	−57	−9
					18	5.79	−43	15				
10	17	14.18	NA	NA	19[a]	13.87	NA	NA	18[a]	21.62	NA	NA
	18	13.22	13	−7	20	11.26	127	−19	19	14.49	−11	−33
	19	13.45	13	−5	21	13.56	0	−2	20	19.03	0	−12
					22	14.17	42	2				

[a]CT currently employed protocol.

and pitch[15, 34–36]. The Catphan® 600 CT QA phantom has been employed by previous researchers to analyse the influence of exposure parameters on image quality[22, 24, 25, 37]; however, none of these studies included paediatric protocols.

Phase 2: image quality evaluation with Radia Diagnostic® software

CNR is considered a good method of evaluating CT images[14, 20, 37] as noise is the primary limiting parameter of CT image quality. According to image analysis manufacturer, clinical studies comparing image quality levels show that trained observers (subjective evaluation) and RIT's Radia Diagnostic® software (objective evaluation) render similar results[33], adding confidence to the methodology used here. Radia Diagnostic® software proved to be a good method for protocols selection based on CNR.

Phase 3: optimisation with age-specific APs

The CT protocols currently employed were found to be categorised by children's age; however, age subsets used varied across the three centres and these were not aligned to international paediatric radiography guidelines recommendations[38]. Authors recommend the formulation of age-categorised protocols[39–41], as

re-iterated in the paediatric European guidelines for radiography[38]. The need for age-related protocols are justified, otherwise paediatric CT examinations will result in some patients receiving higher than optimal radiation dose values[42, 43]. A non-standardised and limited approach to age categorisation was identified in the three paediatric centres. These protocols were tested on the Catphan® 600 and APs and repeated using the age categorisations as defined by European guidelines on quality criteria for diagnostic radiographic images in paediatrics[38] and as found in European paediatric CT DRL's studies[26, 27]. The majority of the currently employed dose values were higher than the European CT DRL's studies[27–29, 44] and the optimisation tests allow similar or lower CT dose values.

Phase 4: anthropomorphic image quality evaluation with OsiriX® software

Anthropomorphic phantoms have been employed in several previous studies that were aimed at optimising CT practice, and in addition, OsiriX software has been incorporated to evaluate image analyses using mean pixel values and the standard deviation of pixels in an ROI[36, 45–48]. This method was applied in this work in addition to the inclusion of age-specific categorisation and more realistic tissue-equivalent for paediatric CT dose studies[26, 27, 38]. In image processing low standard deviation values in a homogenous area represents a low level of noise, normally associated with higher dose values applied during imaging[49].

For chest CT examinations, the majority of the standard deviation differences were found to be lower with the new parameters than with the currently employed parameters (Table 5); these results correspond to reduced image noise levels following optimisation. It was noted that as dose reductions rose to 50 %, increases in standard deviation values were recorded.

Similar findings occurred across the three paediatric centres for the newborn head CT examinations (Table 4). For 5- and 10-y-old phantom head CT examinations, the standard deviation percentage varied between 4 and 44 % and 12 to 58 %, respectively. These findings demonstrated that the currently employed head CT protocol was more suitable for imaging 10-y-old patients than for 5-y-olds, suggesting substantial potential to optimise imaging parameters for 5-y-old patients (mean dose decrease of 20 %), with a reduced impact on image noise when compared with findings of 10-y-olds.

Global discussion

This study identified that minor exposure parameter manipulations, involving tube current–time product and tube voltage reduction (<60 mAs and 30 kV for head CT examinations; <30 mAs and 30 kV for chest CT examinations), resulted in paediatric CT mean dose reductions of up to 26 %. The use of reduced tube voltages for head CT examinations resulted in inferior but not significantly different CNR values (mean variation ± 0.2), and the CTDIvol levels decreased by 31 % across the centres, the least variation in CNR values being recorded for smaller patients. The manipulation of tube current proved of increased benefit for the head CT examination as the currently employed high values allowed manipulation to aid optimisation for all three centres. For chest CT, the manipulation of tube voltage resulted in a mean variation of 0.15 in CNR, across the centres. The CTDIvol decreased by 23 %, and the pre-optimisation tube current was less varied across the three centres, than demonstrated for head examinations. The exposure parameter manipulations were undertaken with consideration of both the equipment design and patient size, allowing a reduction of CT dose levels with no significant impact in image quality.

Discussion with relevant clinical parties following review of the optimisation process and experimental testing has supported the introduction of age-categorised protocols in alignment with European guidelines[38] across the three centres, and local review of the protocols was enacted. One centre opted for a software upgrade to define new protocols with the most recent technological potentialities for CT optimisation, as tube current and tube voltage modulation, this was initiated following consultation involving the research group and the clinical management team.

LIMITATIONS

Due to the variation in CT equipment across the three centres, it was not appropriate to test matching protocols across centres. Further investigation involving an increased number of centres with comparable equipment may facilitate the potential to investigate a greater range of protocol options currently being clinically applied on scanner models.

The experimental work involved phantom images and the use of an objective image noise measures. For Catphan® 600 images, the CNR was obtained with the RIT's Radia Diagnostic® software, and for AP images, the image noise of homogenous ROIs was measured with OsiriX® Imaging software; however, it was not possible to convert these noise measurements to Hounsfield Units. The incorporation of optimised clinical images for image quality review would also aid in demonstrating the impact of noise levels upon radiology image interpretation.

CONCLUSIONS

Catphan® 600 phantom, CNR analysis, age-categorised APs and image noise analysis were employed with the aim of identifying optimisation strategies for head and chest paediatric CT examinations. The manipulation of tube current–time product,

tube voltage, pitch, slice thickness and acquisition mode facilitated mean percentage dose reductions of 36, 25 and 32 % for head CT examinations and 9, 29 and 40 % for chest CT examinations, respectively, for Centres A, B and C. Paediatric CT dose reduction potential was identified with minimal impact on image noise.

In line with the European recommendations, this study included four age categories and recommends this for use in clinical practice and for consideration when developing imaging scanning protocols. The findings of this work have demonstrated the potential to lower tube voltage and current for newborns. The manipulation of scanning parameters should be carefully considered on individual bases with regard to patient age/size as indicated by this research.

The optimisation experiments performed in the clinical centres raised awareness locally with regard to CT protocol selection. The experimental optimisation findings are currently being used to aid protocol review locally in all three centres. This research group is continuing work in the centre that upgraded its CT software as a direct impact of the findings of this research. Comparisons of radiation dose and image quality levels within patient images, pre- and post-software upgrading, using anatomical criteria is proceeding.

It is recommended that further communication between specialised Paediatric centres regarding imaging protocols and methods of age categorisation could further promote a decrease in paediatric CT exposure.

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