Pediatric chest HRCT using the iDose⁴ Hybrid Iterative Reconstruction Algorithm: Which iDose level to choose?

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Abstract. Purpose of the study is to determine the appropriate iterative reconstruction (IR) algorithm level that combines image quality and diagnostic confidence, for pediatric patients undergoing high-resolution computed tomography (HRCT). During the last 2 years, a total number of 20 children up to 10 years old with a clinical presentation of chronic bronchitis underwent HRCT in our department’s 64-detector row CT scanner using the iDose IR algorithm, with almost similar image settings (80kVp, 40-50 mAs). CT images were reconstructed with all iDose levels (level 1 to 7) as well as with filtered-back projection (FBP) algorithm. Subjective image quality was evaluated by 2 experienced radiologists in terms of image noise, sharpness, contrast and diagnostic acceptability using a 5-point scale (1=excellent image, 5=non-acceptable image). Artifacts existence was also pointed out. All mean scores from both radiologists corresponded to satisfactory image quality (score ≤3), even with the FBP algorithm use. Almost excellent (score <2) overall image quality was achieved with iDose levels 5 to 7, but oversmoothing artifacts appearing with iDose levels 6 and 7 affected the diagnostic confidence. In conclusion, the use of iDose level 5 enables almost excellent image quality without considerable artifacts affecting the diagnosis. Further evaluation is needed in order to draw more precise conclusions.

1. Introduction
The large number of computed tomography (CT) examinations taking place in everyday clinical practice has increased the risk for radiation-induced carcinogenesis and has made CT radiation dose a nowadays top safety concern in health care. This concern is much stronger for children who are more radiosensitive and have longer life expectancy than adults [1].

The use of iterative reconstruction (IR) algorithms in CT examinations has been proved useful for reducing radiation dose intake, while preserving image quality [2, 3]. However, there still remains a question which IR algorithm level to choose in order to combine minimal image noise with maximum diagnostic acceptability, as higher IR levels have been proved to be connected with blotchy, pixelated or oversmoothing artifacts providing a ‘non-natural’ image [3, 4].

The purpose of this study is to determine the appropriate Hybrid iDose IR algorithm level for the chosen image settings (mAs, kVp) used in our radiology department in children often in need for repetitive chest high-resolution computed tomography (HRCT) examinations with the indication of chronic suppurative lung disease.

2. Materials and Methods
The present cohort study had the approval of our hospital ethics committee.
2.1 Patient Population
We retrospectively reviewed preschool and preadolescent school-aged pediatric patients, under the age of 10 years old, who underwent chest HRCT examinations after the installation of iDose\(^4\) IR algorithm in our Radiology Department. All the patients suffered from chronic suppurative lung disease.

According to the review, a total number of 24 children with the indication of chronic suppurative bronchitis underwent the specific examination since 2012 using the iDose IR algorithm. For technical reasons and mainly because of poor cooperation and severe motion artifacts, 4 of them were excluded. Therefore, a total number of 20 pediatric patients finally participated in the study (Table 1).

Table 1. Patients’ characteristics. Data are presented as mean ± standard deviation and range in parentheses.

| Characteristics | 5.53 ± 1.35 (4-9.5) |
|-----------------|---------------------|
| Age (yr)        |                     |
| No of patients  | 20                  |
| Male/Female     | 7/13                |
| Weight (kg)     | 19.92 ± 3.06 (14.7-28) |

2.2 Acquisition protocol
All the HRCT examinations were performed in a 64-slice multidetector CT (MDCT) scanner (Brilliance, Philips Healthcare, Cleveland, OH, USA), using 80kVp voltage and 40-50 mAs settings. In addition, all examinations were reconstructed using both FBP algorithm and all iDose levels (levels 1 to 7), in order to draw conclusions for the appropriate kVp, mAs settings and iDose level combination.

HRCT scanning protocol included non-contiguous axial slices (every 1cm) from lung apex to base for inspiratory scans, and limited (3 to 4) spaced HRCT slices for expiratory scans, using 1.25mm slice thickness. The rest CT scanning parameters included supine patient positioning, 64 x 0.625mm detector configuration, 0.5sec gantry rotation time and a sharp filter (YC – Philips Healthcare, Cleveland, OH).

2.3 Subjective Image Quality
The subjective image quality of all the aforementioned examinations was evaluated independently by 2 experienced radiologists (A with 22 years of experience and B with 8 years of experience) for noise, sharpness, contrast and diagnostic acceptability using a descending five-point scale (Table 2). According to this scale grade 1 corresponds to excellent image quality, grade 5 corresponds to non-acceptable image quality, whereas grade 3 constitutes the threshold for diagnostic acceptable image. The overall image quality was estimated as the average value of image noise, sharpness and contrast scores. The presence of artifacts (respiratory, metallic, oversmoothing, blotchy or pixelated appearance etc.) affecting the diagnosis was also pointed out.

Table 2. Subjective image quality evaluation

| Noise                  | Sharpness                          | Contrast            | Diagnostic acceptability |
|------------------------|------------------------------------|---------------------|--------------------------|
| 1 No noise             | Excellent sharpness of structures   | Excellent contrast  | Superior                 |
| 2 Minimal noise        | Good sharpness of structures        | Very good contrast  | Good                     |
| 3 Average noise, not   | Acceptable sharpness                | Acceptable contrast | Average                  |
| 4 Above average noise, | Difficulty in distinguishing         | Slight contrast     | Suboptimal               |
| affecting the diagnosis|                                    | enhancement         |                          |
2.4 Statistical analysis

Interobserver agreement between the two radiologists was evaluated using kappa (k) test with k<0.20 signified poor agreement; k=0.20–0.40, fair agreement; k=0.41–0.60, moderate agreement; k=0.61–0.80, good agreement; and k=0.81–1.0, almost perfect agreement. The statistical test was performed using the Superior Performance Software System (SPSS, v 21.0, SPSS Inc., Chicago, IL, USA).

3. Results

The interobserver agreement showed a good agreement between the 2 independently working radiologists (k>0.628). There also was an expected progressive improvement in image quality from iDose level 1 to iDose level 7 reconstruction algorithm for all the aforementioned parameters (noise, sharpness, contrast and diagnostic acceptability).

A remarkable notice was that all mean scores from both radiologists were from 1 to 3, even with the FBP algorithm use, which is considered an acceptable score as it corresponds to a satisfactory image quality, without important noise affecting the diagnosis. Almost excellent image quality (score <2) was obtained with iDose levels 5, 6 and 7.

The presence of artifacts affecting the diagnosis was also assessed, with the majority relating to respiration or motion artifacts and in one case artifacts from metallic implants. The existence of these artifacts in most of the cases affected the diagnostic acceptability, but not to such an extent as to render the examinations non-diagnostic (scores up to 3). Additionally, artifacts responsible for blotchy or pixelated appearance described in literature were not observed in this study, whereas oversmoothing artifacts coming from the use of high levels of iterative algorithms were only noticed with iDose levels 6 (6/20 of children) and 7 (8/20 of children). Despite the fact that in our study oversmoothing artifacts did not have a negative impact on the subjective evaluation of contrast or sharpness (scores almost equal to 1), whenever noticed an issue of imaging interpretation arose, because the final CT image outcome was far from our radiologists’ everyday diagnostic experience and familiarization. In these cases, the radiologists who participated in our study remained slightly reserved in scoring. But since these artifacts were only observed in a small number of children, mean diagnostic acceptability evaluation of iDose levels 6 and 7 practically was not affected, as shown in table 3.

Table 3. Subjective image quality evaluation. Data are presented as mean scores from both radiologists-observers participating in the study.

|                | FBP | iDose1 | iDose2 | iDose3 | iDose4 | iDose5 | iDose6 | iDose7 |
|----------------|-----|--------|--------|--------|--------|--------|--------|--------|
| Noise          | 2.9 | 2.8    | 2.6    | 2.3    | 1.9    | 1.8    | 1.4    | 1.2    |
| Sharpness      | 2.8 | 2.7    | 2.6    | 2.2    | 1.9    | 1.6    | 1.4    | 1.1    |
| Contrast       | 2.6 | 2.5    | 2.3    | 2.1    | 1.7    | 1.5    | 1.4    | 1.1    |
| Diagnostic     | 2.5 | 2.4    | 2.4    | 2.2    | 2.1    | 1.9    | 1.6    | 1.4    |
| acceptability  |     |        |        |        |        |        |        |        |
| Overall image  | 2.6 | 2.6    | 2.5    | 2.1    | 1.9    | 1.6    | 1.4    | 1.1    |
| quality        |     |        |        |        |        |        |        |        |

4. Discussion

As already mentioned, the aim of this study was to determine the appropriate iDose level providing excellent image quality for the chosen kVp and mAs settings in children’s chest HRCT examinations. Two more studies for chest CT with a similar reasoning have been conducted so far, one for adults by Singh et al. [5], using 30%, 50%, and 70% of Adaptive Statistical Iterative Reconstruction technique (ASIR) blending, and one by B. Karmazyn et al. [6] for children’s chest-abdomen with FBP and iDose
levels 2 to 6. The first one [5] revealed mild pixilated blotchy texture only with 70% blended ASIR images and the second one [6] showed that iDose levels 3 and 4 were optimal for most cases.

According to the subjective image quality evaluation of our study, excellent subjective image quality (score equal or almost equal to 1) was only achieved with the use of iDose level 7 and almost excellent image quality (score <2) was obtained with iDose levels 5 and 6. However, among the aforementioned levels, iDose level 5 was the only one not accompanied by oversmoothing artifacts. The existence of these artifacts, as already explained, affected our experienced pediatric radiologists’ diagnostic confidence by leaving them with doubts concerning CT image reliability. This resulted in them preferring for diagnosis a lower iDose level with less good scores concerning noise, contrast or sharpness, over higher iDose levels with an admittedly excellent overall image quality (average of noise, contrast and sharpness scores).

An important observation as well, was that subjective overall image quality was always evaluated up to 3 (acceptable image quality), even with the use of the FBP algorithm. According to this observation, future investigation with further reduction of mAs settings could be achieved without affecting the diagnostic outcome.

Among the limitations of this particular study concerning chest HRCT with the use of iDose IR algorithm for chronic suppurative bronchitis was the small number of the participating pediatric patients. This suggests that so far the advantages of the IR technique are not sufficiently widespread in the medical world and the concern of pediatricians towards young patients’ radiation exposure still remains. The limited number of patients participating in the study can be partially attributed as well to the fact that there were non-cooperative children during the CT scans. These children had to be excluded from the study due to significant motion artifacts, as they were considered to be affecting the results concerning diagnostic acceptability.

In conclusion, our study results imply that iDose level 5 could provide almost excellent image quality for our radiology department’s chosen kVp and mAs settings, without any substantial artifacts affecting the diagnostic outcome. Further evaluation with even more patients and lower mAs settings could lead to safer conclusions for this ‘sensitive’ patient group in need for repetitive chest HRCT examinations.

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