ORIGINAL ARTICLE

Computed tomography in children with cystic fibrosis: a new way to reduce radiation dose

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Aims: To determine whether the monitoring of respiratory disease progression in children with cystic fibrosis (CF) can be made using six pre-selected computed tomography (CT) cuts in lieu of the conventional full study.

Methods: Forty one lung CT scans from 21 paediatric patients with CF were analysed. The Bhalla and Nathanson scores of the total lung CT and the six pre-selected CT cuts were compared.

Results: The Bhalla mean score of the total lung CT evaluated by two radiologists was 5.62. It was 5.36 when just the six pre-selected sections were evaluated. The difference between means was not statistically significant. The Nathanson mean score of the total lung CT evaluated by both radiologists was 66.11; it was 66.51 when just the six pre-selected sections were evaluated. The difference between means was not statistically significant. The mean total radiation dose from a single whole lung CT scan was 716.22 mGy.cm. A dose of 250.66 mGy.cm was estimated if only six sections were used, with a reduction in radiation of about 65%.

Conclusion: It is possible to obtain the same radiological information from six pre-selected CT cuts as it is from a full pulmonary CT scan, thereby markedly reducing radiation exposure for children who will require repeat investigations in the future.

Cystic fibrosis (CF) is the most common serious inherited disease, affecting between 1 in 2000 and 1 in 4000 children of Caucasian origin. Pulmonary disease is the major cause of morbidity, also being responsible for 90% of deaths in patients with CF.¹

Several clinical and radiographic scores have been used to monitor the pulmonary status of these patients.^{2–5} The advent of high resolution computed tomography (HRCT) has allowed early detection of pathological changes, and even mild degrees of bronchiectasis and mucoid impaction.⁶ Several HRCT scoring systems have been developed to describe and quantify lung pathology, the most commonly used being those of Bhalla and Nathanson.^{7–8} Others have published modifications of these scoring systems.^{9–10}

Computed tomography (CT) was first introduced around 1973, with its main disadvantage being the radiation exposure to patients. CT scans are now the major cause of radiation for children.¹¹ The A-bomb survivors represent the best source of data for risk estimates of radiation induced cancer.¹² People exposed 50 years ago to doses comparable to those associated with a helical CT, today show a small, but statistically significant excess incidence of cancer. An abdominal helical CT scan in a young girl results in a risk of fatal cancer later in life of about one in a thousand. The risk for one person is small, but the public health implications are significant when a small personal risk is multiplied by the 2.7 million such procedures that are performed annually in the USA.¹² Children are 10 times more sensitive to radiation induced cancer than adults, their lifetime cancer mortality risk being inversely proportional to their age. There is also a significant difference between sexes, girls being twice as sensitive as boys.¹³

In order to minimise the radiation children receive from CT, two strategies can be applied. The first is the judicious use of CT, performing only examinations with absolute indications, and limiting these to the area in question. The second one is modifying CT scan technical parameters in accordance with the size of the child, trying to avoid multiple sequences

or cuts during the same CT study (for example, minimising dual phase studies (pre- and post-contrast)).¹⁴

Patients affected by CF undergo multiple radiological examinations in their lifetime, including CT. As these examinations are planned systematically, patients are receiving a high dose of radiation that could be lowered by reducing the number of CT cuts.

The aim of this study was to determine whether the monitoring of respiratory disease progression in children with cystic fibrosis can be made using six pre-selected CT cuts in lieu of the conventional full study, therefore markedly reducing the radiation exposure.

METHODS

A retrospective study was performed reviewing 41 CT lung examinations of 21 children diagnosed with CF and followed up in the Cystic Fibrosis Unit of the Paediatric Department in the Hospital Universitario Central de Asturias, Spain.

The study group included 14 female and 7 male patients between 1 month and 16 years of age (median 7.5 years). They were diagnosed with CF between 1 month and 46 months of age (median 5.5 months).

CT scans (n=41) were performed on three different scanners in the Department of Radiology of the Hospital Universitario Central de Asturias: Elscint CT Twin Flash; Picker CT Twin Flash; and General Electric Light Speed Ultra. After a scout view, collimation sections between 1 and 6.5 mm were found, at intervals of 3, 5, 8, 10, or 15 mm, as appropriate for the child's size. All scans were done with 120 kV, 100/130 mA, with exposure times between 1 and 3 seconds, resulting in 100–300 mAs. Two CT scans were done by conventional CT combined with HRCT for technical reasons. All were performed in the supine position. Older children were asked to hold their breath at maximal inspiration. CT scans were assessed by two experienced radiologists.

Abbreviations: CF, cystic fibrosis; CT, computed tomography

Table 1 Inter-observer variation of radiologists assessing chest CT scans

	Radiologist 1 (Mean $\pm$ SD)	Radiologist 2 (Mean $\pm$ SD)	t test	95% CI*
Bhalla score—total lung CT scans	5.4 $\pm$ 3.1	5.6 $\pm$ 3	0.8	–1.5 to 1.3
Bhalla score—6 CT cuts	5.2 $\pm$ 2.9	5.5 $\pm$ 2.9	0.691	–1.6 to 1.1
Nathanson score—total lung CT scans	66.1 $\pm$ 4.9	66.1 $\pm$ 5	1	–2.3 to 2.3
Nathanson score—6 CT cuts	66.5 $\pm$ 4.5	66.5 $\pm$ 4.8	1	–2.2 to 2.2

*If 0 is included in the confidence interval the difference between the means is not statistically significant.

Every CT was scored according to the Bhalla and Nathanson^{7,8} scores. The initial assessment included just the six pre-selected cuts, followed on a different day by assessment of the entire CT chest series.

The six chosen cuts, selected by their easy location were: at the pulmonary apex, below the clavicles; at the aortic arch; just below the tracheal carina; below the pulmonary hilae; where the greatest cardiac diameter is found; and where the diaphragmatic dome starts. In every scan, technical parameters (mAs, kV) were analysed.

European guidelines on quality criteria for CT¹⁵ have been published by the European Commission, in which two dose descriptors, weighted computed tomography dose index (CTDI_w) and dose-length product (DLP), were proposed as reference dose levels. CTDI_w provides the radiation dose from one slice at particular exposure settings and DLP characterises the exposure from a complete examination. DLP increases in direct proportion to the number of cuts of the examination.

CTDI¹⁵ was measured using a pencil shaped ionisation chamber of active length 100 mm. This was placed in a body phantom and the total lung CT radiation exposure was estimated according to the DLP formula.¹⁵ The DLP was calculated for the total lung CT and was also estimated if only six cuts were taken.

Statistical analysis was performed with the SPSS software package (version 11.0), comparing the data obtained from the CT assessed with the six chosen cuts with the data obtained from the total lung CT.

Spearman rank correlation was used to relate Bhalla and Nathanson CT scores to disease duration. A two tailed p value of <0.05 was considered significant.

RESULTS

Our 21 children were aged between 1 month and 16 years (median age 7.5 years). The 41 lung CT scans included 10–47 sections (median 16). Four of the 41 scans were of insufficient quality to be evaluated and were thus excluded from the analysis.

The mean total radiation dose from a single whole lung CT scan was 716.22 mGy.cm (range 178.2–3432). Using the same equipment and technical parameters, the mean total for only six sections was 250.66 mGy.cm.

Table 1 shows the inter-observer variability. As there was no statistically significant difference between observers, each CT was assigned a mean score for comparison of the total lung CT with those of the six pre-selected cuts (table 2).

The Bhalla score mean assessing all cuts was 5.62; it was 5.36 when just the six pre-selected cuts were evaluated. This difference was not statistically significant.

The Nathanson score mean assessing all cuts was 66.11; it was 66.51 with just the six pre-selected sections. Again the difference between both means was not statistically significant.

A statistically significant correlation was found between the Bhalla and Nathanson scores and the disease duration ($r_s = 0.707$, $p < 0.01$; $r_s = -0.657$, $p < 0.01$ respectively).

DISCUSSION

We report an alternative to using whole chest CT scans for the prospective evaluation of chronic respiratory disease in children with cystic fibrosis. Our data suggests that six pre-selected cuts, using almost one third of the radiation, provide the same clinical detail as the conventionally employed whole chest CT scan. The study was performed in children younger than those in previously reported studies.^{6,9,16–20} At such a young age (median 7.5 years), it is particularly important to seek ways of minimising radiation exposure in investigations that are frequently repeated.

The first studies reporting the use of low dose CT scanning technique appeared in the 1990s, suggesting that adequate images could be obtained despite reducing the radiation dose.^{21,22} In fact, the search for reducing radiation exposure has been particularly critical for paediatric radiologists. The ALARA (As Low As Reasonably Achievable) Conference²³ in 2001 concluded that the highest priority should be given to reducing the radiation dose while still maintaining acceptable (diagnostic) image quality. The conventional way of achieving this is by using low dose CT. Brody *et al* in 1999 did suggest obtaining fewer scans at greater intervals;²⁴ however a study like ours has not been published to date.

We chose these six specific cuts from the scout films as the majority of lung tissue could be evaluated using simple anatomical landmarks. This technique is only of use in the routine monitoring of disease severity in patients with chronic lung disease, as many more cuts would be indicated were it important to identify a specific lesion.

Although both radiological scores showed less severity when only six sections were evaluated, the differences between these scores and those of the more detailed scan were not statistically significant. There was an excellent correlation between disease severity measured by both radiological scores and the duration of time from diagnosis, confirming the validity of these scores in clinical practice.

There was a 65% reduction in the radiation dose when using only six cuts. In routine practice this reduction in radiation may not be as pronounced. Several of the CT studies we reviewed were done for specific lesions and therefore used more cuts than would be used routinely in a follow up study. Most monitoring scans for children with CF would use about 12 cuts/study, and as a result, we would expect a reduction in radiation dose of about 50%.

Two CT scans were performed by conventional CT combined with HRCT for technical reasons. We used these CT scans, but the results were the same: six cuts did not differ significantly from the total number of cuts. We do not believe that there would be any significant change in the study results, and therefore they were included in the study.

Although plain x ray examinations of the chest have been shown to be a useful and reliable measure of disease progression,²⁵ and appear to correlate very well with physiological disease deterioration, increasing interest has focused on the use of CT images to detect potentially reversible lesions before they become an irreversible part of disease progression. It is clear that changes in pulmonary function tests lag behind subtle changes in the respiratory

What is already known on this topic

- CT scans are the major cause of radiation for children; they are 10 times more sensitive to radiation induced cancer than adults
- The highest priority should be given to reducing the radiation dose while still maintaining acceptable image quality

architecture.²⁶ Brody *et al* have shown that measurements too sensitive for plain radiography can document structural change that may help predict disease progression and evaluate treatment response.²⁷ Although these measurements are still not well correlated with clinical outcome, it is likely that in due course these increasingly sensitive investigational techniques will allow earlier, more tailored use of specific disease modifying interventions.²⁸ In many chronic inflammatory diseases physicians now seek to intervene much earlier, trying to modify the course of the disease itself. As a result we need robust and reproducible measures of disease progression. It is clear, however, that both investigations and the interventions they prompt must be appropriately assessed to ensure they are achieving their aims.

This paper does not recommend the frequency of follow up investigations. As a result we are unable to determine the total reduction in exposure over the lifetime of a "typical" patient. However, a 50% reduction becomes even more important if repeat scans were increasingly performed to detect preclinical changes.

Although our study sample is relatively small, the data clearly highlights the potential benefit in selecting cuts to minimise radiation in children requiring regular chest CT scans to monitor disease progression in cystic fibrosis. Larger studies should be done to confirm this finding. In conclusion, this study shows that six predetermined cuts from a chest CT provide an equally sensitive measure of disease severity as a more detailed study, thereby reducing the radiation exposure by at least 50% per study.

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What this study adds

- In children with CF, it is possible to obtain the same radiological information from six pre-selected CT cuts as it is from a full pulmonary CT scan
- This reduces radiation exposure

Table 2 Comparison of scores in assessing a total chest CT vs. six cut study

	Total lung CT scans (Mean $\pm$ SD)	6 CT cuts (Mean $\pm$ SD)	t test	95% CI*
Bhalla score	5.6 $\pm$ 3	5.4 $\pm$ 2.8	0.7	-1.1 to 1.6
Nathanson score	66.1 $\pm$ 4.8	66.5 $\pm$ 4.6	0.7	-2.6 to 1.8

*If 0 is included in the confidence interval the difference between the means is not statistically significant.