Pediatric protocols and dose reduction devices in CT scanners where few examinations are performed

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Abstract

Increased awareness of patient doses related to CT examinations has inspired the invention of various dose reduction features, as well as stressed the importance of pediatric protocols. The aim of our study was to evaluate factors related to scanner design and setup that might result in considerable differences in radiation dose between geographic areas.

We examined the preset protocols and the technical features regarding dose reduction; automatic exposure control (AEC), iterative reconstruction (IR), automated kV selection and organ based dose modulation.

As expected the availability of dose reduction devices is highly, but not entirely, dependent on the manufacturing year of the scanner. In general, protocol optimization is more lacking than technical features. The majority of the scanners did not have age and/or weight categorized pediatric protocols and the dose reduction made possible with iterative reconstruction methods is not yet available everywhere.

Introduction

Increasing number of computed tomography (CT) examinations in the last decades has raised concerns especially regarding the pediatric population [1]. There are though indications of improvements, for example in specialized pediatric hospitals where the use of CT imaging has begun to decrease [2] and radiation doses are lower [3].

The increased radiation dose awareness has inspired important technical improvements in the area of dose reduction. Automatic exposure control (AEC) with tube current modulation (TCM) is now a well established technique which can reduce patient doses considerably [4]. Among the emerging techniques in the last decade that can result in relevant dose reductions are; iterative reconstruction (IR) [5,6], automated kV selection [7], and organ dose modulation [8]. These new technologies are generally not all available in all scanners, especially not in the older ones.

It is known that for the same procedure, patients’ radiation dose can vary considerably and more than 10-fold variation in estimated median effective dose for a baby has been reported within trauma center facilities [9]. One of the most important things to do is to “child size” the amount of radiation used [10], by using pediatric protocols and implement all the available dose reduction technologies in each scanner.

There was a 20\% increase in the number of CT examinations in Iceland from 2008-2013. A substantial amount of all CT examinations is done in CT scanners in which less than 5000
examinations are done per year and those scanners might not be equipped with optional technical features. 

In scanners where pediatric examinations are few and far between it is difficult to establish a reliable evaluation of patient doses for each procedure. One way to evaluate the situation is to examine the preset protocols and the dose reduction techniques available in the respective scanners.

The aim of our study was to evaluate factors related to scanner design and setup that might result in considerable differences in radiation dose between geographic areas.

**Materials and method**

All scanners outside the Reykjavik-capital area were included, in each of them relatively few CT examinations are performed (less than 5000/year) in contrast to CT scanners in the more densely populated capital area. Existing data about number of examinations in 2013 was mined to collect information about examination frequency and proportion of pediatric examinations. We visited each scanner and examined the technical features regarding dose reduction; AEC, IR, automated kV selection and organ based dose modulation. Note that the last two are not available from all CT vendors. In the same visit we examined the preset protocols in every scanner to confirm if there were pediatric protocols, how many, how they were labelled and if dose reduction devices were used. At last we asked the radiographers if and when pediatric protocols were used.

**Results**

Outside the Reykjavík-capital area there are seven scanners, and they were all included in the study. The oldest scanner in the study was from 2004 (11 years), the mean age was 5 years, and two of the scanners were new (2015). There were three General Electric scanners, two Toshiba and two Siemens scanners.

In the year 2013 21% of all CT examinations in Iceland were performed with the seven scanners included in this study, and the remaining 79% were performed in the five clinical CT scanners in the Reykjavík-capital area.

Pediatric examinations are on average 3% of all examinations, and the highest proportion of pediatric examinations is at the University hospital (5%). In all the scanners included in this study (scanners were few examinations are performed, outside the capital area) the proportion of pediatric examinations was 2-4%.

There were pediatric protocols for head CT in all seven scanners, but in the majority of scanners there was only one pediatric protocol as shown in Figure 1.

Two of the seven scanners (29%) had no pediatric abdomen protocols. In four scanners (57%) there was one pediatric abdomen protocol and one scanner had abdomen protocols based on weight groups. The lowest kV was 100kV.

All of the seven scanners had three dimensional AEC but none of them had organ based dose modulation.
One scanner (14%) had the availability of automated kV selection, but at the time of the study the automated kV selection was not yet implemented in the pediatric protocols. IR is available in the three newer scanners (2013 and newer), 1st generation IR in one scanner and 2nd generation in two, but not in the four older ones (2004-2010). In all three scanners with IR it was implemented in the pediatric abdomen protocols, but only in one scanner in the head protocols.

**Discussion**

As expected the availability of dose reduction devices is highly dependent on the manufacturing year of the scanner, but not entirely. An interesting example is that the only scanner with the automated kV selection is the second oldest of all the scanners.

All scanners had some preset protocols for pediatric examinations but some only for head CT. Radiographers confirmed that this reflects the requests for pediatric CT, where head CT is more often requested than abdomen CT. Radiographers in hospitals near Reykjavík claim that they purposefully direct pediatric abdominal CT to the University hospital and our data supports that.

We did though assume that pediatric protocols were necessary in all scanners and that kV should be lower for the smaller children, because one method to lower the radiation dose is to use lower kV when the subject is small (11). Without automated kV selection, automatic tube current selection is generally not enough to optimize dose and image quality in pediatric patient because a lower limit on the tube current may restrain the dose reduction. Pediatric protocols also ensure that an appropriate beam shaping filter is used.
There might be a different need for age or weight based pediatric protocols depending on scanner manufacturer, based on difference in scanner design. An example of this is that while some types of AEC modulate the tube current directly according to image noise, other types take into account that in smaller patient the inherent contrast is less and thus less noise is needed for similar perceived image quality (12).

AEC is not recommended in head protocols in all scanner types and thus these protocols often have fixed mA. We found that this was often the case and unfortunately there was only one pediatric protocol in majority of the scanners, a fact from which we can assume that many of the larger children are scanned with adult protocols. It was confirmed at one site that adult protocol was used for all patients aged 8 years and older.

IR was available in three scanners but interestingly it was only used in head protocols in one of them although it was always used in abdomen protocols when available. This might reflect that dose reduction is considered more important in abdomen CT than head CT, but radiographers also mentioned that radiologists do not accept the altered appearance (texture) of the images that result from the IR.

In general, protocol optimization is more lacking than technical features. The majority of the scanners did not have age and/or weight categorized pediatric protocols (Figure 2) and the dose reduction made possible with IR is not yet available everywhere.

![Figure 2](image_url)

*Figure 2 The number of scanners with (green) and without (red) age categorized pediatric head protocols, weight categorized pediatric abdomen protocols, automatic exposure control, iterative reconstruction and automated kV selection. *Not available from all vendors.

Although data on examination frequency showed that pediatric examinations were performed in all scanners included in the study we found more than one example indicating that pediatric
protocols were neglected. Two examples of this are that; a) where automated kV selection was recently installed the technique was not implemented in the pediatric protocols although it was in the adult protocols, and b) where radiographers were not aware that there were pediatric protocols in the scanner and thus did not use them.

In conclusion, the dose reduction techniques that can be expected according to scanner age are available but the pediatric protocols are few in most scanners and need improvement.

References


