Procedure for optimal implementation of automatic tube potential selection in pediatric Computed Tomography (CT) to reduce radiation dose and improve workflow

Quality Improvement Project

Jacinta E. Browne, Ph.D.[1], Michael R. Bruesewitz, R.T.(R)[1], Vrieze Thomas, R.T.(R)[1], Kristen B. Thomas, M.D.[1], Nathan C. Hull, M.D.[1], Cynthia H. McCollough, Ph.D.[1], Lifeng Yu, Ph.D[1]

[1]Department of Radiology, Mayo Clinic, Rochester, MN

Background and Aim

- CT is an important imaging technique for the detection and staging of disease across the abdominopelvic region of pediatric patients [1].
- While imaging a pediatric population with ionizing radiation it is important that dose reduction techniques are employed.
- A number of optimization tools for radiation dose reduction have been successfully implemented in adult CT scanning protocols; one important technique is to adjust tube potential (kV) [2,3].
- One such tool is an automatic tube potential (kV) selection tool, CAREkV which selects the optimum kV based both on the patient size and the diagnostic task [4].
- The aim of this quality improvement study is to describe the procedure to clinically implement an automatic kV selection tool for radiation dose reduction in pediatric abdominopelvic CT using the

  "Plan Do Study Act" process.

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[1] Yu et al. AJR. 2015; 205:1026–1037. **[2]** McCollough et al. Radiographics 2006; 26:503-512.
[3] Yu et al. Radiographics 2011; 31:835-848. **[4]** Hough et al. AJR. 2012; 199 1070-1077.

PLAN : Design of Quality Improvement project

Plan : *for optimal implementation of automatic tube potential selection in pediatric CT to reduce radiation dose , improve image quality and workflow*

Do

Phantom Study

- 6 semi anthropomorphic phantoms were scanned on a dual-source 128-slice scanner using a routine pediatric abdominopelvic protocol (Flash, Siemens) with ***CAREkV on*** and ***off***

Clinical Implementation

- The optimal CAREkV clinical task settings were chosen by the pediatric radiologists and CT protocol committee based on similarity of the kV settings for different patient sizes and clinical tasks, to the existing technique chart settings. The optimal CAREkV settings identified in step 1 were programmed into a new pediatric CT protocol, which was used clinically over a 1-month trial.

Study

Objective Performance Evaluation

- Retrospective patient data corresponding to the use of the manual technique chart was collected for the 3 month period prior to the start of the study.
- During the evaluation period, prospective patient data was collected for the 3 months while using CAREkV. Then the dose and image quality metrics for CAREkV were compared to that achieved previously in a similar patient cohort using the manual technique chart.

Act

CT Pediatric Practice change

- CAREKV was clinically adopted into our pediatric abdominopelvic CT practice at the end of this quality improvement process which incorporated the ***PDSA*** approach.

Do : Step 1 - Phantom Study

- Siemens Flash scanner
- 6 semi anthropomorphic phantoms (0yrs, 1yr, 5yrs, 10yrs, 15yrs and young adult – CIRS, Model 007TE).
- Current technique chart
- CarekV
  - Reference technique: 120 kV, 160 QRM
  - slider bar selections: 2, 3, 5, 6, 8 and 11
  - Optimal kV and CTDIvol were recorded for each setup and phantom

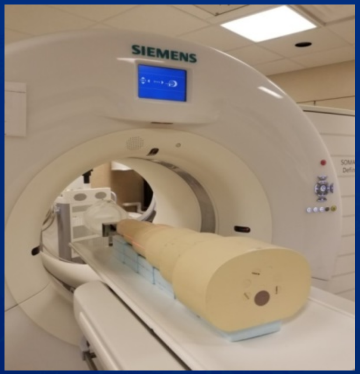

Figure 1: Phantom set-up

Table 1. Current technique chart used in pediatric abdominal CT exams

	< 8 kg		8-30kg		>30 kg	
	kV	QRM (mAs)	100 kV	QRM (mAs)	80 kV	QRM (mAs)
With IV-contrast	80	460	100	220	120	120
Non-contrast	120	160	120	160	120	160

** Current kV/mAs technique chart, was previously developed in a comprehensive clinical evaluation [3]

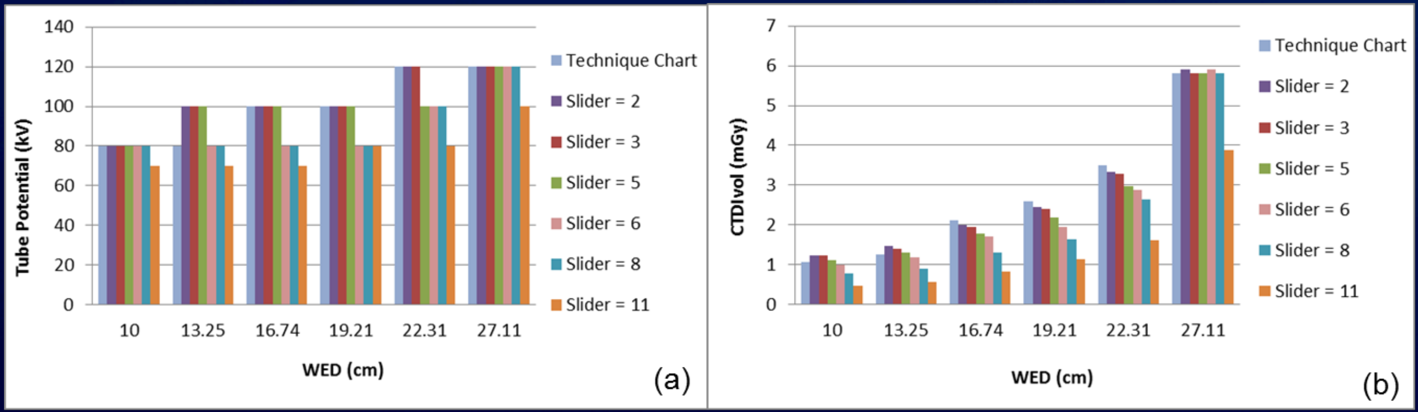

Figure 2: (a) Tube Potential (kV) selection and (b) radiation dose (CTDIvol) used for the different phantom sizes and slider-bar settings

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[3] Yu L et al. Radiographics 2011; 31:835-848.

Do : Step 2 - Clinical Implementation pilot study

The optimal CAREkV clinical task setting was chosen by the pediatric radiologists and CT protocol committee based on similarity of the kV settings for different patient sizes and clinical tasks, to the existing technique chart settings.
These optimal CAREkV settings were programmed into a new pediatric CT protocol, which was used clinically over a 1-month trial period.

Table 2: CAREkV Recommended kV - **S**ummary of tube potential selection by CAREkV for the different phantom sizes and slider-bar settings

	WED (cm)	Pre-term 10cm	Newborn 13.25cm	1 year 16.74cm	5 year 19.21cm	10 year 22.31cm	15 year 27.11cm	Small Adult 27.11cm
Non-contrast	Non-contrast clinical task- Slider 2	80	100	100	100	100	120	120
	Slider 3	80	80	100	100	100	120	120
Contrast	Slider 5	80	80	100	100	100	100	120
	Slider 6	80	80	80	80	80	100	120
	Slider 8	80	80	80	80	80	100	120
	IV contrast clinical task - Slider 11	70	70	70	70	80	80	100

Study : Objective Performance Evaluation

Patient data, corresponding to the manual technique chart was collected for the 3 month period prior to the start of the study and prospective patient data was collected for the 3 month period after the start of the study. The collected data included the following:

i. patient size (Water-Equivalent-Diameter);
ii. clinical task – non-contrast exam / contrast-enhanced exam;
iii. kV and CTDIvol;
iv. image quality metrics - the average liver noise, average liver and iodine enhanced aorta Hounsfield values and CNR.

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Study : Objective Performance Evaluation

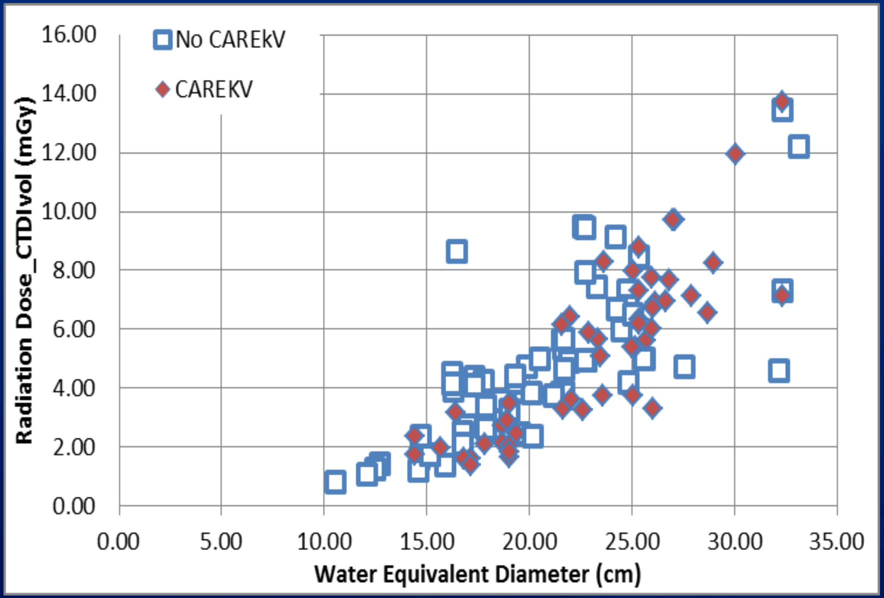
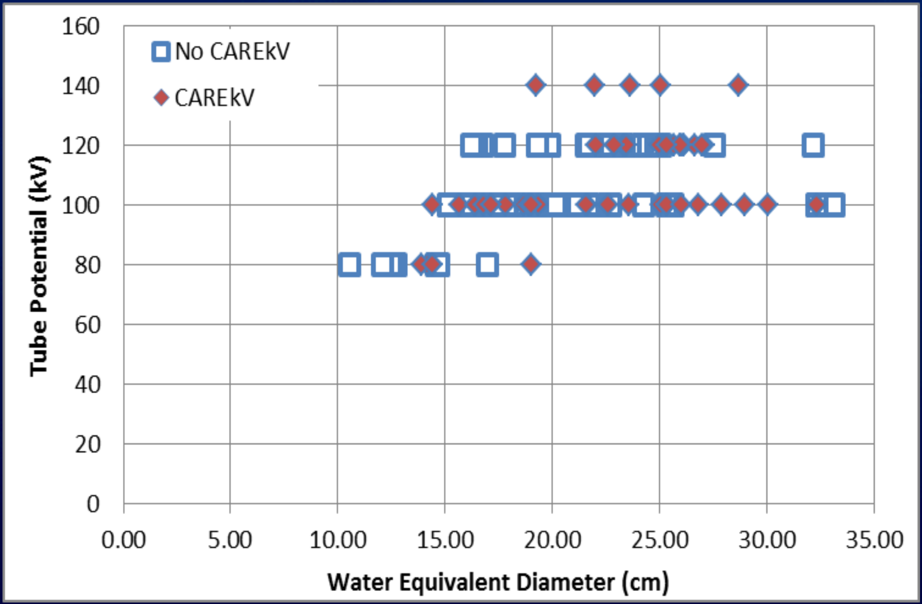


Figure 3: CTDIvol of patients of different sizes ***before*** use of CAREKV (No CAREKV, n=65) and ***after*** use of CAREKV (CAREKV, n=56); both groups had similar patient cohorts (comparison between WEDs from each group, p=0.4).

No significant difference between the $CTDI_{vol}$ using the optimized technique chart (No CAREkV) and the automatic kV selection technique, CAREkVfor the different patient sizes

Figure 4: kV used for patients of different sizes and clinical tasks ***before*** use of CAREKV (No CAREKV, n=65) and ***after*** use of CAREKV (CAREKV, n=56).

CAREkV was found to select a higher tube potential, 140 kV ($p<0.05$) for patients with larger WED for a small group of patients; these patients were found to have a pear-shaped or a non-optimum set-up (legs apart)



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Results

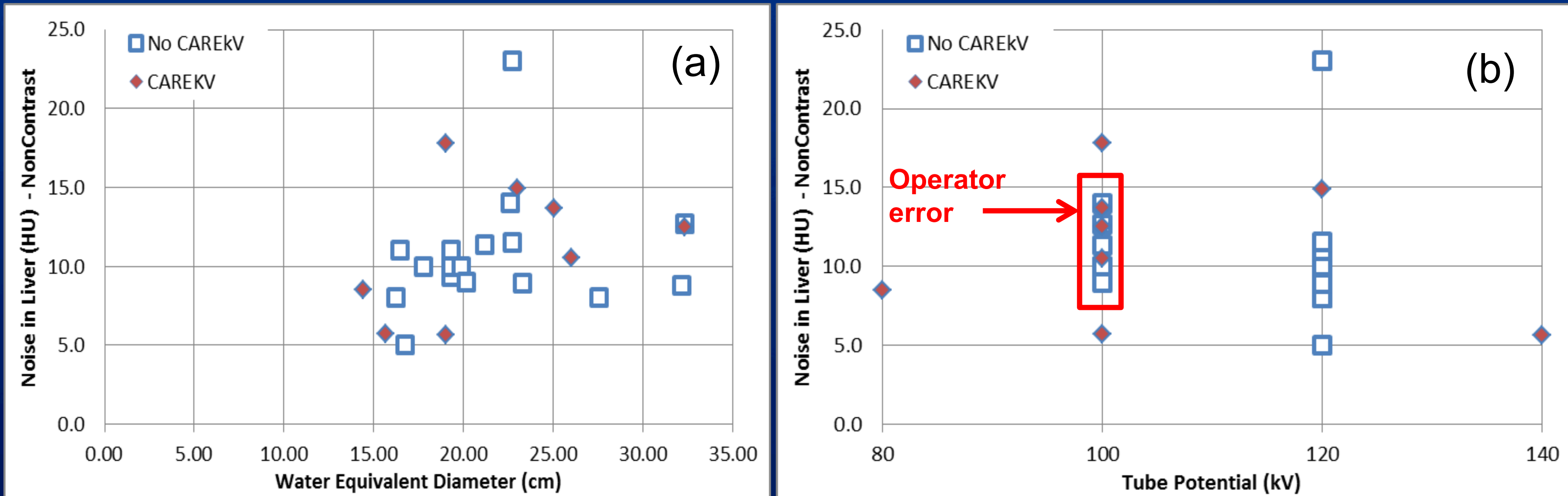

Figure **6:**(a) **Noise in liver for non-contrast exams** for patients of different sizes and (b) **Noise in liver** for **non-contrast exams** and corresponding kV selected for patients of different sizes ***before*** (No CAREKV, n=65) and ***after*** use of CAREKV (CAREKV, n=56).

It was found that there was no significant difference (p=0.8) between the **Noise in liver** for non-contrast exams ***before*** the use of CAREKV and ***after*** the use of CAREKV.

Furthermore, it was found that a number of non-contrast examinations protocoled using the manual technique chart were incorrectly setup using 100 kV rather than120 kV, indicating the ***presence of operator-error*** in protocol setup.

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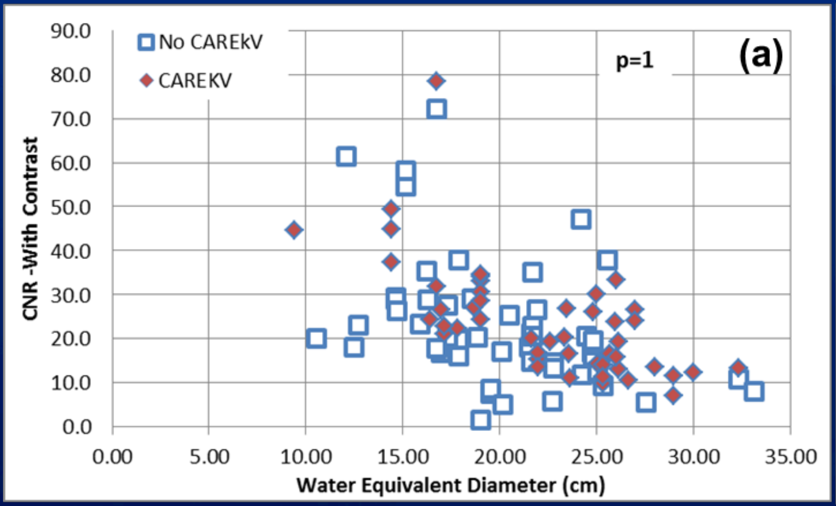
Results



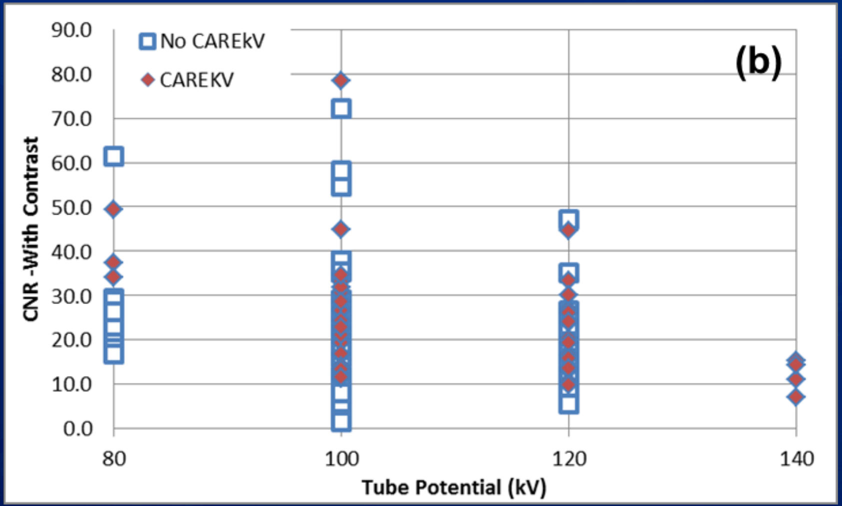


Figure 7: (a) CNR for contrast-enhanced exams for patients of different sizes and (b) CNR for **contrast-enhanced exams** and corresponding kV selected for patients of different sizes ***before*** use of CAREKV (No CAREKV, n=65) and ***after*** use of CAREKV (CAREKV, n=56).

It was found that there was no significant difference (p=1) between the CNR for contrast-enhanced exams ***before*** the use of CAREKV and ***after*** the use of CAREKV.

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<u>A</u>ct : **Clinical Implementation of CAREkV** into routine pediatric abdominopelvic CT exams

The optimal CAREkV clinical task setting for different patient sizes and clinical tasks were programmed into the pediatric CT protocol for abdominopelvic CT exams.

Based on the results from the objective performance evaluation, the CAREkV CT protocol was further refined to exclude the choice of 140 kV from the tube potential selection, so as to provide the benefits of improved contrast and dose reduction at lower tube potentials.

This new pediatric CT protocol for abdominopelvic exams will be reviewed annually as part of CT protocol management.

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Conclusion

- CAREKV was optimally adopted into our clinical pediatric abdominopelvic CT practice through the use of the PDSA quality improvement process.
- This ensured that optimal image quality was maintained relative to our kV/mAs technique chart which was rigorously-developed in a previous clinical study, and that an appropriate radiation dose reduction was incorporated by the CAREkV tool through the careful selection of the clinical task parameter settings.
- This tool provides the benefits of potentially lower radiation dose, a streamlined workflow and a reduction in operator-error in the protocol set-up.

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