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

Quality Improvement Project

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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.

**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

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

<table>
<thead>
<tr>
<th></th>
<th>&lt; 8 kg</th>
<th>8-30kg</th>
<th>&gt;30 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>kV</strong></td>
<td>80</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td><strong>QRM (mAs)</strong></td>
<td>460</td>
<td>220</td>
<td>120</td>
</tr>
<tr>
<td><strong>With IV-contrast</strong></td>
<td>120</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td><strong>Non-contrast</strong></td>
<td>120</td>
<td>160</td>
<td>120</td>
</tr>
</tbody>
</table>

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

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**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 - Summary of tube potential selection by CAREkV for the different phantom sizes and slider-bar settings

<table>
<thead>
<tr>
<th>WED (cm)</th>
<th>Pre-term 10cm</th>
<th>Newborn 13.25cm</th>
<th>1 year 16.74cm</th>
<th>5 year 19.21cm</th>
<th>10 year 22.31cm</th>
<th>15 year 27.11cm</th>
<th>Small Adult 27.11cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-contrast</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Non-contrast clinical task</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Non-contrast clinical task Slider 2</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Non-contrast clinical task Slider 5</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>120</td>
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<tr>
<td>Non-contrast clinical task Slider 6</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>120</td>
</tr>
<tr>
<td>Non-contrast clinical task Slider 3</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>IV contrast clinical task</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>80</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>IV contrast clinical task Slider 11</td>
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<td>70</td>
<td>70</td>
<td>70</td>
<td>80</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

### 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.
**Study**: Objective Performance Evaluation

*Figure 3*: CTDI\_vol 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, CAREkV for 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).
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 protocolled using the manual technique chart were incorrectly setup using 100 kV rather than 120 kV, indicating the **presence of operator-error** in protocol setup.
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.
**Act  : 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.
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.