A province-wide approach to CT dose optimisation in Québec, Canada

Several studies have linked an increase of lifetime risk of cancer to the radiation exposure in CT examinations. This has prompted many countries to take action and to consider CT exposure as a public health problem. The province of Québec (Canada) has created the Center of clinical expertise in radiation safety (Centre d’expertise clinique en radioprotection, CECR) to gather knowledge and communicate best practices related to the use of ionizing radiation in a medical context. Since 2011, the CECR has conducted a province-wide tour of 180 CT installations in order to evaluate the performance CT scanners and to initiate, with local stakeholders, a CT dose optimization process. This paper presents the multidisciplinary and collaborative approach developed by the CECR.

INTRODUCTION
CT is the largest source of population exposure to medical ionizing radiation around the world [1, 2] and recent studies have shown a statistically significant increase of lifetime risk of radiation-induced cancer from CT examinations [3,4,5]. In 2008, CT was responsible for 52% of the medical exposure to ionizing radiation in the province of Québec (Canada) [6]. Data collected from the provincial universal health care program showed a continuous augmentation in CT studies since then, with an increase of 45% between 2008 and 2013. The degree of population exposure can be expressed in terms of diagnostic reference levels (DRLs), obtained through national or regional surveys. In the field, these DRLs values are often used as dose limits rather than guidelines. For an efficient optimization of patient doses, DRLs must be used with other parameters such as the capabilities of CT equipment, patient size, and diagnostic image quality requirements. This is not a trivial, one-size-fits-all task and significant efforts must be made to achieve an optimal use of dose in CT.

In order to promote a more rational use of radiation in medicine, the province of Québec has created the Centre d’expertise clinique en radioprotection (CECR), a provincial center of clinical expertise in radiation safety with the mandate to support the Ministry of Health and Social Services in reducing medical radiation exposure. As part of its mandate, the CECR initiated in 2011 a province-wide tour of 180 CT sites in order to: (i) evaluate the technical and functional performance of CT scanners, (ii) evaluate and improve radiation safety practices and (iii) initiate a dose optimization process of routine CT protocols [7]. Over a period of four years, ending in 2015, 112 installations have been optimized.

ON-SITE VISITS
The tour consisted of two-day visits to CT facilities conducted by a team of medical physicists (or biomedical engineers) and medical imaging technologists. Weeks prior to the visit, the CECR contacted the facility to gather information on the equipment and the CT protocols used. The objectives of the tour and the overall progress of the visit were explained during this first contact, and the CECR asked the hospital to designate technologists, managers and radiologists to participate during the visit. The visits began with a meeting between CECR experts and local technologists, managers and radiologists to explain the approach and the objectives of the visit. The emphasis was put on the collaborative nature of the approach, so that local stakeholders do not wrongly believe that this was a formal inspection. Then, CECR experts performed quality assurance tests on monitor display (AAPM TG18) as well as on CT equipment [8, 9]. They also evaluated local radiation safety practices and analyzed 30 recent adult studies and 15 pediatric studies provided by the hospital. Acquisition and reconstruction technical parameters, CTDIvol, dose length products, noise levels, scan ranges and image artifacts were verified.

The second day also began with a meeting between CECR experts and local technologists, managers and radiologists to explain the approach and the objectives of the visit. The emphasis was put on the collaborative nature of the approach, so that local stakeholders do not wrongly believe that this was a formal inspection. Then, CECR experts performed quality assurance tests on monitor display (AAPM TG18) as well as on CT equipment [8, 9]. They also evaluated local radiation safety practices and analyzed 30 recent adult studies and 15 pediatric studies provided by the hospital. Acquisition and reconstruction technical parameters, CTDIvol, dose length products, noise levels, scan ranges and image artifacts were verified.

The visits began with a meeting between CECR experts and local technologists, managers and radiologists to explain the approach and the objectives of the visit. The emphasis was put on the collaborative nature of the approach, so that local stakeholders do not wrongly believe that this was a formal inspection. Then, CECR experts performed quality assurance tests on monitor display (AAPM TG18) as well as on CT equipment [8, 9]. They also evaluated local radiation safety practices and analyzed 30 recent adult studies and 15 pediatric studies provided by the hospital. Acquisition and reconstruction technical parameters, CTDIvol, dose length products, noise levels, scan ranges and image artifacts were verified.

The second day also began with a meeting with the local team where the CECR presented its observations and recommendations, notably regarding ways to improve the clinical practice and to optimize CT protocols. With the consent of local radiologists, optimized CT protocols were used for CT studies
scheduled on this second day. Finally, at the end of the visit, a report summarizing all CECR observations and recommendations was delivered to the local team as well as to the head of the institution.

In the weeks following the visit, the local team of radiologists were asked to evaluate up to 30 CT exams performed with the optimized protocols. This evaluation was conducted with quality scoring forms and sent back to the CECR.

1. QUALITY ASSURANCE PROGRAM

The vast majority of CT devices inspected achieved the CECR performance criteria, with only 9% of them failing to meet one or two performance criteria. However, the data collected showed that there is room for improvement in quality control (QC) practices, which varied significantly from one facility to another. For this reason, the CECR published in 2013 a QC and radiation safety manual for CT installations [9] to help CT facilities to progressively implement standardized QC practices.

2. DOSE REDUCTION THROUGH GOOD CLINICAL PRACTICE

Clinical practices, under the responsibility of radiologists and executed by technologists, have a significant impact on the overall radiation dose delivered to the patients. Based on the analysis of 30 routine studies provided by the hospital, the recommendations of CECR experts regarding clinical practices included items such as reducing the scan coverage to the minimum required for diagnostic purpose, centering the patient adequately in the CT gantry and using bismuth shielding when there is no medical contraindications. The analysis of clinical studies showed that: i) scanning beyond predefined anatomical landmarks recommended by the CECR occurred in 25%, 39% and 25% of hospitals visited for the head, chest and abdomen-pelvis protocols respectively. Overscanning ranged from 10 to 40 mm, ii) patient positioning was not adequate in 15% of CT facilities visited and iii) about 25% of visited CT hospitals did not own bismuth shielding for breast, thyroid and eyes. 43% of hospitals visited did not use this shielding when available and 22% used it occasionally.

3. DOSE REDUCTION THROUGH SCAN PROTOCOL OPTIMIZATION

The success of CT protocol dose optimization relies on two important factors. The first one is the acknowledgement of radiologist’s expectations for image quality: spatial resolution, noise and contrast-to-noise ratio. The second is the comprehension of how different acquisition and reconstruction parameters influence, independently and together, image quality and associated radiation dose. Full consideration of these expectations along with the knowledge of CT device capabilities are essential in the judicious choices of acquisition and reconstruction parameters that achieve an adequate image quality for a particular indication and patient morphology, at the lowest achievable radiation dose. Published guidelines [10] suggesting technical parameters for specific CT devices constitute a good starting point for optimization, but in general this process requires fine-tuning and discussions with radiologists. More than 80% of routine adult head, chest and abdomen-pelvis protocols were modified during on-site visits. Table 1 reports the statistics on dose reduction achieved for protocols that were modified. Overall, significant dose reductions were achieved, in some cases with values as high as 60%.

CONCLUSION

The objective of the CECR CT tour was to initiate a dose optimization process within each hospital visited, with the hope that local teams would take over in the long run. The CECR approach to optimize CT doses is based on the active participation of all stakeholders in the process and takes into account the performances of CT scanners, the opinion of radiologists and the availability of dose reduction tools (current modulation, iterative reconstruction). The diagnostic quality required by local radiologists remained central in the optimization process. This multidisciplinary and collaborative approach, based on support, guidance and the physical presence of CT imaging experts, was very well accepted and led to significant dose reductions. The CECR continues to support hospitals remotely and with follow-up visits, with the objective of promoting a rationale use of ionizing radiation in medicine.

REFERENCES


<table>
<thead>
<tr>
<th>Routine protocols</th>
<th>Avg.</th>
<th>min</th>
<th>max</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>19%</td>
<td>6%</td>
<td>60%</td>
<td>12%</td>
</tr>
<tr>
<td>Chest</td>
<td>24%</td>
<td>2%</td>
<td>50%</td>
<td>11%</td>
</tr>
<tr>
<td>Abdomen-pelvis</td>
<td>20%</td>
<td>5%</td>
<td>52%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Table 1: Dose reduction achieved for modified adult protocols.