Implementation of an innovative management strategy of dose and good practices in computed tomography

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Aims and objectives

Introduction

Owing to broader indications, CT use is increasing around the world. In 2012, the French Institute for Radiological Protection and Nuclear Safety (Institut de Radioprotection et de Sûreté Nucléaire, IRSN) estimated that 71 % of the medical exposure in France was due to Computed Tomography (CT) [1]; a 22 % increase of the dose was noted over the past five years mainly due to CT as the number of standard X ray examinations is decreasing at a rate of 2% per year. Radiologists and health professionals are aware of this problem and dose optimization of CT is a major concern for patient care [2, 3]: recent works [4, 5, 6] show a higher risk of leukemia and glioma in patients who underwent a CT scan during childhood. In addition, some studies [7] show that beyond the organ-specific radio-sensitivity, there is also a genetic individual radio-sensitivity. Malfunctions of DNA repair capabilities even for low exposure (about 1 mGy) doses can now be identified thanks to advances in biology [8].

Optimal dose reduction first requires that the relevance of each exam as mentioned in the EURATOM 2013/59 Directive, can be justified. To meet this requirement, the French Society of Radiology, together with the Nuclear Safety Authority, the High Authority of Health and the French Society of Nuclear Medicine released an updated guide addressing the "appropriate use of medical imaging examinations" [9]. This is a comprehensive data repository to guide physicians looking for the best imaging test to answer a clinical situation or disease.

Decrease of CT dose is also a challenge for the R & D section of manufacturers developing new detectors or new reconstruction algorithms for this purpose. Radiation protection based on the "As Low As Reasonably Achievable" principle (ALARA) [10] is hence increasingly applied in Medical Imaging: the examinations should be achieved using the minimum dose required to ensure the proper diagnosis.

Current CT offer new reducing dose technologies, such as iterative reconstruction or automatic exposure control. However, these techniques need to be properly configured to be useful [11]. In addition, changes in primary acquisition parameters influence both dose and Image Quality (IQ) [12, 13]. To our knowledge there is no practical guide to optimize the new techniques mentioned above. Indeed, several tools for monitoring patient dose (Dose Archiving and Communication System, DACS) have been recently proposed by the manufacturers. These systems archive cumulative patient dose from any x-ray modality. They allow the detection of poor acquisition practices. Nevertheless, none of these propose a support to radiological teams in order to correct wrong CT protocols settings and malpractice.
As far as we know, there is no similar solution to drive radiologists and medical physicists in their optimization campaign despite the fact that guidelines were promoted by the American Association of Physicists in Medicine (AAPM) in order to be implemented by healthcare professionals [14].

In their guidelines, addressing the development of a CT protocol management strategy, AAPM especially recommends the following steps:

- to create user accounts with specific administrators for protocol edition,
- to clean the protocol database: removing duplicates, non used protocols, practices standardization, protocols classification,
- to match CT systems in radiology department,
- to implement tools monitoring patient dose in order to personalize protocols.

Nevertheless, in clinical practice, with DACS system, the last step is difficult to fulfill without an adequately designed study description thesaurus.

**Objective**

To report the impact of a novel study description thesaurus for optimal follow up of CT dose reduction in clinical practice.
Methods and materials

Dose Management Team creation in association with DoseWatch® DACS

A multidisciplinary team, named Dose Management Team, dedicated to CT protocols management strategy using the DoseWatch® (GE HealthCare) DACS, was established by gathering:

- referent senior radiologists,
- one medical physicist,
- dedicated technicians.
- DoseWatch® support engineers.

Novel study description thesaurus to implement CT protocol management

The Dose Management Team designed a study description thesaurus according to four items (as defined in fig. 1) that could be implemented in each radiology department which uses DoseWatch® DACS.

The study descriptions are selected manually by technicians within CT acquisition console during exam identification.

Alert thresholds were configured in DoseWatch® as two times of the total DLP 75th percentile based on clinical practice. Then, these thresholds were assigned to the three following BMI ranges:

- BMI < 18.5,
- 18.5 < BMI < 30,
- BMI > 30.

To adopt a personalized CT protocols policy, kVp modulation was manually applied by technicians. For the first BMI range, technicians had to decrease by 20 kVp the sequences voltage. For the middle BMI range, no kVp modulation had been set. For the superior BMI range, technicians had to increase by 20 kVp the sequences voltage. This kVp modulation was applied to exams where chest and/or abdomen and/or pelvis was/were scanned.

The CT protocol management workflow with DoseWatch® DACS could be resumed as shown in Figure 2.

Clinical study of two study descriptions
Two types of most frequently used study descriptions were selected in this study. On one hand, the "TAP:Onco:Multi Phases" (TAP: Thorax Abdomen Pelvis) study description, which referred to common CT examination for follow-up of oncologic patients, was analyzed for the following examination panel:

- 23 examinations with patient's BMI inferior to 18.5,
- 350 examinations with patient's BMI between 18.5 and 30,
- 70 examinations with patient's BMI superior to 30.

On the other hand, the "TAP:H.T:Three Phases" (HT: Hepatic transplantation) study description, which referred to common CT examination addressing the characterization of liver lesions, was analyzed for the following examination panel:

- 25 examinations with patient's BMI inferior to 18.5,
- 377 examinations with patient’s BMI between 18.5 and 30,
- 73 examinations with patient's BMI superior to 30.

With these study descriptions, alert thresholds were introduced to evaluate our clinical practice constancy. Also, effective dose were estimated according to European recommendations [15].
Fig. 1: Novel study description thesaurus diagram designed in four items. "TAP" and "AP" terms respectively referred to thoracic-abdominal-pelvic examination and abdominal-pelvic examination. "Onco" and "hemato" terms respectively referred to oncology and hematology clinic. GSI®, HR, VEO® were specific acquisition technics for the Discovery CT750 HD system (GE HealthCare).

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Fig. 2: Examination workflow principal steps diagram. First, technicians had to manually select the corresponding study description within acquisition console. Then, they performed the CT exam according to the radiologist instructions. Finally, they analyzed exams above alert threshold in direct link with the medical physicist. By following these steps, which led to practices homogenization, Local Diagnostic Reference Level (LDRL), based on total DLP per exam and number of sequences, could be established.

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Results

"TAP:Onco:Multi Phases" study description analysis

As shown in Figure 3, alert thresholds evolution for the "TAP:Onco:Multi Phases" study description were evaluated. During this study, two phases could be observed: first, an implementation step of the novel study descriptions thesaurus; then, kVp manual modulation strategy input. During the second study step, our alert thresholds were constant (except for the high BMI range because of kVp manual modulation that was not perfectly used yet) while mean patient's BMI per range resumed constant. Henceforth, for this study description, these alert thresholds could be the basis to create Local Diagnostic Reference Level (LDRL).

"TAP:H.T:Three Phases" study description analysis

As shown in Figure 4, alert thresholds evolution for the "TAP:H.T:Three Phases" study description were evaluated. During our analysis, the same previous phases could be observed. During the second analysis step, no alert thresholds were constant although mean patient's BMI per range were approximately constant. This situation was normal for the two extreme patient's BMI ranges. However, constant alert threshold was expected for the middle patient's BMI range while this threshold was steadily increasing.

This alert threshold increase could be explained by a poor study description selection by technicians as shown in Figure 5. Indeed, the first part of this evaluation highlighted technicians learning phase for correctly selecting study descriptions.

Effective dose for the two analyzed study descriptions

For the two analyzed study descriptions, effective doses were estimated per patient's BMI range (Table 1.). The obtained values highlighted morphology body impact. As DoseWatch® alert system was based on total DLP per exam, it was necessary to implement alert thresholds also based on patient's range.
Fig. 3: Alert thresholds evolution expressed as two times of the total DLP 75th percentile based on clinical practice for the "TAP:Onco:Multi Phases" study description. The left vertical axis represented alert thresholds expressed in mGy.cm as DLP unit. The right vertical axis represented patient’s BMI. Dotted curves and solid lines respectively referred to patient’s BMI and alert thresholds. Blue, orange and grey curves respectively referred to patient’s BMI inferior to 18.5; between 18.5 and 30; superior to 30. The first part of this graph highlighted study description thesaurus implementation. The second part of this graph highlighted kV manual modulation strategy.

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Fig. 4: Alert thresholds evolution expressed as two times of the total DLP 75th percentile based on our clinical practice for the "TAP:H.T:Three Phases" study description. The left vertical axis represented alert thresholds expressed in mGy.cm as DLP unit. The right vertical axis represented patient's BMI. Dotted curves and solid lines respectively referred to patient's BMI and alert thresholds. Blue, orange and grey curves respectively refer to patient's BMI below 18.5; between 18.5 and 30; superior to 30. The first part of this graph highlights the study description thesaurus implementation. The second part of this graph highlights kV manual modulation strategy.

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**Fig. 5:** Evolution of mean acquisition number per examination for the "TAP:H.T:Three Phases" study description with patient's BMI range between 18.5 and 30. The left vertical axis represented mean acquisition number per examination. The first part of this graph highlights a learning phase as some examinations were below sequences number threshold correlated to study description.

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<table>
<thead>
<tr>
<th>BMI ranges</th>
<th>TAP:ONCO:MULTI IV</th>
<th>TAP:T.H:3H</th>
</tr>
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<tbody>
<tr>
<td>&lt; 18.5</td>
<td>16.7 ± 5.9</td>
<td>17.4 ± 6</td>
</tr>
<tr>
<td>18.5 &lt; &lt; 30</td>
<td>31.4 ± 5.9</td>
<td>35.4 ± 14</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>48.8 ± 12.9</td>
<td>52.4 ± 11.9</td>
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**Table 1:** Effective Doses according to patient's BMI range for analyzed study descriptions. These values were obtained from DLP and specific conversion factors depending on the body area scanned.

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Conclusion

The implementation of a novel study description thesaurus, tailoring dedicated clinical indications, allows a more accurate evaluation of the expected dose achieved by each protocol in clinical routine. Our thesaurus, in association with DoseWatch®, could be adapted for the most common practices. This could lead to novel Dose Level recommendations, named LDRL, defined according to a specific clinical indication. Monthly staff composed by the whole Dose Management Team enabled a control of CT protocols management and an improvement of Dose Management Team members' knowledge.

Whole CT protocols management steps had been summarized by a progress wheel (Fig. 6).

Limitations

Manually applied kV modulation, were some times omitted. Consequently, alert thresholds could have been distorted.

Moreover, since technicians manually selected study descriptions, some cases were not matched with the right description and generated bad alerts while modifying the corresponding alert threshold.
Fig. 6: Progress wheel that summarizes CT protocol management steps. First, CT examinations are performed on patient. Then, DoseWatch® system analyses the clinical practice. Technicians, in collaboration with medical physicist, justify generated alerts. Monthly staffs are organized to analyze practices and educate technicians when necessary. These steps lead to improved clinical practices as examination workflow, image quality / dose ratios are simultaneously taken into account.

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