The Justification principle applied to Computed Tomography exams

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Abstract. The increasing use of imaging technologies and the installation of more sophisticated equipment in radiology services, such as multi-slice CT scanners have consequently increased the number of treated patients, as well as the collective doses to population. Radiation doses received from CT exams are higher than those received in conventional radiology. The optimal use of CT equipment, considering optimized techniques, and the justification of examinations, are imperative in order to minimize the undesirable effects of radiation. In this paper we do set out to the assessment of justification criteria applied for CT exams in a Cuban Hospital. The justification of prescribed tests by physicians was analyzed, assessing its incidence depending on the kind of studies and percentage (%) of positive and negative cases. The study was carried out in a Clinical Surgical Hospital in Havana City. This hospital has installed a Shimadzu SCT-7800TC helical single-slice device. The sample is made up of 81 patients, between 24 and 80 years old, both men and women. For all of them the pathology that causes the order of the exam as well as the existence of other previous tests, were considered. As a result of the assessment, the 56.8% of all cases turned out to be positives; the 55.5% only confirmed the pathologies and the 1.23% produced new evidences. On the other hand, the remaining 43.2% were negatives noting that the 65.3% of the patients there were not previous imaging tests. Skull exam was the most incidences compiling the 67.7% of cases, and it was the headache the most frequent clinical problem to perform the 41.1%. In terms of justification, the evaluation of prescriptions evidenced that CT exams were not justified in 43.2% of cases. As part of this last group, it was also found that 46.9% of clinical studies were negative.

KEYWORDS: Justification, collective doses.

1. Introduction

The increased development and dissemination of medical equipment using ionizing radiation is a reality nowadays in the health care environment. Radiology plays an essential role for the diagnosis, follow up and even the modification of therapeutic conducts in an enormous number of pathologies [1]. This fact has propitiated the extensive use of radiology, in spite of the health risks related to the ionizing radiation exposure of humans [2, 3]. On the other hand, radiology is one of the biggest contributors to the costs for health care, both in terms of financial and human resources.

The accelerated installation of new technologies which provide the higher doses, such as Helical and Multislice Computed Tomography (CT) [4,5], has also caused the considerable increase of the number of diagnostic examinations using these techniques. For all the above mentioned reasons, it results very important as a first condition that radiological examinations being whole justified. This means that physicians should be aware about the expected results and ensure that these results are really necessary to adopt the diagnostic or therapeutic management of patients, giving also priority to other tests which do not cause exposure to ionizing radiation.

The present research tries to evaluate the achievement of the application of justification principle [6] to the more frequent examinations executed in a CT room. To do this, a multidisciplinary group of expert physicians analyzed the prescriptions received in the CT department, evaluating the information contained on these prescriptions, the frequency of examinations, as well as the correspondence between the non justified studies according to prescriptions and those with negative results.
2. Methods and Materials

2.1 Sample selection

The study was carried out in the radiology service of a Cuban hospital in Havana City (hosting institution). The CT room has single slice CT equipment, Shimadzu SCT-7800. Prescriptions were collected during 30 days for the most frequent CT studies: simple skull, thorax, abdomen and lumbar spine. The sample included 81 patients of both sexes, with ages between 24 and 80 years old.

2.2 Research design

The first step was the analysis of the work flow in the service to perform the Radiological CT examinations and collection of prescriptions for the exams included in the sample, according to their frequency. At the same time, a group of specialized physicians for the pathologies included was created: one neurologist and one radiologist from the hosting hospital; one respiratory specialist from the Clinical Surgical Hospital “Hermanos Ameijeiras”; and one orthopaedist from the Orthopaedic Hospital “Fructuoso Rodríguez”. This group evaluated the justification for the use of CT according to the clinical condition of patients.

Positive/negative analysis was performed by the radiologist from the hosting institution, taking into account the confirmation or not of the presumable pathology referred on the prescription, as well as the finding of new evidences. A comparison of cases considered as not justified and those with negative results was made as part of the present research. Complementary, radiation doses given to patients and evaluation of risks associated with those radiation exposures were determined. Additionally, an evaluation of image quality was performed by two radiology experts, using both subjective (anatomical) and objective (physical) criteria.

2.3 Evaluation of image quality

Image quality was evaluated by two methods:

**Subjective Method:** image quality was evaluated according to the opinions of two independent observers (radiologists), taking into account the definition of structures on the anatomical region. [7]

**Objective Method:** through the evaluation of physical parameters, such as noise, low contrast resolution, special resolution and uniformity of CT number.

2.4 Estimation of doses

Estimation of Effective Dose E (mSv) was made using simplified methodologies which are based on ideal approximations of human anatomy from measurements performed in phantoms.

Different quantities [8, 9] were used to estimate E values: Weighted Dose Index (CTDIw), and Dose Length Product (DLP).

To calculate the value of CTDI\(_{100}\), it was used a pencil ionization chamber with active length of 100 mm, and homogeneous cylindrical phantoms of PMMA, with diameters of 16 mm and 32 mm, simulating head and body of adult patients, respectively. CTDI\(_{100}\) value was calculated following the expression:

\[
CTDI_{100} = \frac{R \cdot C \cdot f_c \cdot L}{T}
\]  

(1)
Where:

CTDI\(_{100}\): CT Dose Index calculated for an active length of ionization chamber of 100 mm.
R: measured value for a single rotation.
C: calibration factor of the ionization chamber.
F\(_c\): conversion factor from exposure units to dose (0.00876 Gy/R).
L: length of the ionization chamber.
T: nominal slice width.

The CTDI\(_c\) (center of the phantom) and CTDI\(_p\) (periphery, 10 mm below the phantom surface) \([7, 10]\) were calculated for all cases. Measurements were performed for a single rotation and using the typical technical parameters clinically used. With these values and their combination it was possible to calculate CTDI\(_w\) value, which is an indicator of the average dose on the axial section of the phantom, and is defined as follow:

\[
CTDI_w = \frac{1}{3} CTDI_{100,c} + \frac{2}{3} CTDI_{100,p}
\]  
(2)

Where:

CTDI\(_{100,p}\): represents the average of all measurements made in the 4 positions in the periphery of the phantom.

To estimate the dose given in a CT examination we used the quantity DLP, which related the CTDI value with the real length of the examination, following the expression:

\[
PDL = \sum_i CTDI_w * Ti * Ni
\]  
(3)

Where:
i: is the number corresponding to each series (sequential or spiral) of the examination.
Ti: slice width selected in the beam collimation.
Mi: number of slices or X ray tube rotations in an helical acquisition.
Ni: number of simultaneously acquired sections for multisections or multislice explorations.

Alternatively, DLP value was also calculated for each sequence \([11]\) by the following expression:

\[
PDL = CTDI_{vol} * L
\]  
(4)

Where:
L: Total examination length.
CTDI\(_{vol}\): corrected magnitude defined by IEC \([12]\) as:

\[
CTDI_{vol} = \frac{CTDI_w}{pitch}
\]  
(5)

Where:

\[
pitch = \frac{\Delta d}{NxT}
\]  
(6)

\(\Delta d\): table movement length in z axis, between consecutive scans or per rotation in helical scans.
N * T: beam nominal collimation (mm).
Estimations of $E$ (mSv) were derived from DLP values for each examination using the normalized coefficients:

$$E = E_{DLP} \times DLP$$

Where

$DLP$ (mGy cm): previously defined in equation (3) or (4).

$E_{DLP}$ (mSv mGy$^{-1}$ cm$^{-1}$): normalized effective dose in a specific region.

### 3. Results y discussion

From the analysis made by the multidisciplinary group it was concluded that none of the collected prescriptions fulfil all the quality requirements. Poor writing and illegible were the main causes of the problems found with interpretation and analysis. Results of physical and/or neurological examinations, as well as references to other personal pathologic antecedents (PPA), are frequently omitted on the prescriptions elaborated by the referred physicians. Only 13.8% of prescriptions have these elements included, so the rest were considered not adequately justified.

References to results of other previous imaging examinations were only present in 34.7% of prescriptions. However, the rest of patients were interviewed at the time they arrive to the service regarding previous radiological examinations, and 39.2% of them showed evidences of previous studies, although these examinations and their results were not referred in the prescriptions.

It was also found that in 27.7% of cases the referred physicians did not specify their diagnostic impression as part of the prescriptions. Skull and lumbar spine examinations are the most frequent studies executed in the service, compiling the 47% and 34% of cases, respectively. Figure 1 shows the frequency of CT examinations in the service.

**Figure 1.** Frequency of different CT examinations
Figure 2 shows that justification principle is adequately fulfilled only in 56.8% of cases, being the non-compliance found in the other 43.2% related to the omission of relevant information on the prescriptions. On the other hand, 46.9% of cases included in this last group had negative results.

**Figure 2.** Distribution of cases according to the compliance with the justification principle

The above mentioned shows the insufficient patient's initial evaluation, which is reflected on the evaluated prescriptions due to:

- Scarce clinical information, which made it impossible to have enough elements to validate the use of CT examinations or another type of alternative imaging technique.
- Lack of complementary exams.
- Mention to clinical facts which are not in correspondence with the requested examination.
- Incomplete clinical evaluation of patients, which made it impossible to evaluate their evolution

The analysis of the correspondence between the suspected clinical problems identified by the referred physicians and the results emitted by the radiologist showed that 56.8% of cases were positive. Of this group, the suspected pathology was confirmed in 55.5% of cases, and new evidences were found in the other 1.23%.

Negative results were found in 43.2% of cases. Skull examinations were the ones which contributed the more to this result, constituting the 67.6% of negative examinations. On the other hand, **headache** was the most frequent clinical problem referred on the prescriptions. Figure 3 shows the distribution of cases by types of CT examination performed.

**Figure 3.** Distribution of cases by type of CT examination performed
3.1 Image quality evaluation

3.1.1 Subjective method (anatomical criteria)

In general, image quality obtained good results for thorax and abdomen examinations, with the 100% of clinical studies fulfilling the quality criteria. Regarding the evaluation of image quality for skull examinations, problems with the correct visualization of grey/white mater frontier and basal ganglia were observed in the majority of studies, which were related to limitations of the CT scanner in terms of low and high contrast resolution.

For lumbar spine examinations, both radiologists found many difficulties to perform the evaluation, because many of the visualization criteria could not be seen without the use of intravenous contrast. On the other hand, thecal fat and paravertebral ligaments were also not well visualized. Radiologists also proposed that two criteria (thecal fat and thecal sac) should be unified and analyzed as unique criteria, because they have a strong relationship. Additionally, other anatomical criteria should be included because of their relevance for the clinical evaluation of patients, such as the correct visualization of yellow ligaments.

3.1.2 Objective Method (Physical criteria)

Evaluation of image quality according to physical criteria showed that all the considered parameters were in compliance with the recommended tolerances. Table I shows the results of this evaluation.

**Table I. Results of the evaluation of physical parameters.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Slice Width (mm)</th>
<th>Results</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Uniformity of TC number</td>
<td>10</td>
<td>-0.9 UH</td>
<td>5 UH</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>-1.5 UH</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>-1.5 UH</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-1.9 UH</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-2.4 UH</td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td>10</td>
<td>0.23 %</td>
<td>≤ 1 %</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.25 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.31 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.39 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.79 %</td>
<td></td>
</tr>
<tr>
<td>Low Contrast Resolution</td>
<td>10</td>
<td>4 Objects were observed (4, 6, 8 and 10 mm, respectively)</td>
<td>According to Manufacturer</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>4 Objects were observed (4, 6, 8 and 10 mm, respectively)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spheres of 2 mm of diameter were not observed for any of the slice width tested.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Contrast Resolution</td>
<td>10</td>
<td>AI 50 %: 3.00 lp/mm AI 10%: 5.75 lp/mm AI 5%: 6.50 lp/mm AI 2%: 7.75 lp/mm 0%: 10 lp/mm</td>
<td>According to Manufacturer</td>
</tr>
</tbody>
</table>
3.2 Dose estimation

Results of CTDI\(_w\) and DLP are shown in Figures 4 and 5 for each examination. All the results are below the Guidance Levels for radiodiagnosis.

**Figure 4.** Estimated average values of CTDI\(_w\) for each examination

![Estimated average values of CTDI\(_w\) for each examination](image1)

**Figure 5.** Estimated average values of DLP for each examination

![Estimated average values of DLP for each examination](image2)
The E values (mSv) obtained in our research are in agreement with those reported by other authors in previous studies. Comparisons with the results reported by other authors are shown in Figure 6.

**Figure 6.** Comparison of estimated average effective dose with other values reported in previous studies.

![Comparison of estimated average effective dose with other values](image)

4. **Conclusions**

1. There is not a justification procedure in place in the hosting radiology service. For that reason all the prescribed CT examinations are performed, without an individual analysis of their appropriateness or not.

2. At the moment of this research, the radiologist from the hosting institution did not have the authority to refuse the execution of any unjustified CT examination.

3. There is not a communication mechanism between the referring physician (the physician who requests the CT examination) and the radiologist. This situation is worrisome, because, for example, it is impossible to request additional clinical information of patients, in case it is needed.

4. In the opinion of the authors, there is a tendency of using diagnostic methods and equipment, instead of clinical examination, as the principal method to evaluate the clinical condition of patients.

5. There was a high percent of cases (43.2%) which were considered not justified for CT examinations, so patients were unnecessarily exposed to radiation, increasing the collective dose to the population.

6. Except for lumbar spine CT examinations, where the radiologists made some recommendations, the image quality criteria established by the European Community were well accepted and constituted a very useful tool for the evaluation.

**Acknowledgements**

The authors wish to thank Fleitas Estevez I., Bejerano Portela G. for their collaboration in revising this paper.
REFERENCES

[9]. Wall BF, Harrison RM, Spiers FW. Patient dosimetry techniques in diagnostic radiology. The Institute of Physical Sciences in Medicine, IPSM. 1988; Report 53.