Physica Medica 29 (2013) 470–477

Contents lists available at SciVerse ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

A quantitative comparison of data evaluation methods to derive diagnostic reference levels for CT from a dosimetric survey: Correlation analysis compared to simple evaluation strategies

Robert Leithner, Peter Homolka*

Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Währinger Gürtel 18-20/4L, 1090 Vienna, Austria

ARTICLE INFO

Article history:
Received 14 August 2012
Received in revised form
18 December 2012
Accepted 3 January 2013
Available online 9 February 2013

PACS:
84

Keywords:
Diagnostic radiology
Diagnostic reference levels
Radiation protection
Patient dose
DRL

ABSTRACT

Objectives: To compare simple and sophisticated evaluation strategies for CT dosimetry surveys with focus on DRLs.
Methods: Based on data from a nationwide Austrian CT dose survey, different evaluation strategies are compared. These were pooled data analysis, weight banding excluding data from patients with weights outside ±20 kg of the standard weights (70 and 75.6 kg representing the actual average weight), and a regression method estimating DLP probability distributions for the standard patient for each scanner before calculating quartiles.
Results: In the abdomen and chest region, weight restriction (−9% and −4% around 70 and 75.6 kg, respectively, compared to pooled data analysis) and statistically weighting each scanner equally (−9%) have the largest effect on DRLs derived. However, the difference in 3rd quartiles calculated using weight restriction alone compared to regression analysis is relatively small (<1% for 70 ± 20 and −6% for 75.6 ± 20 kg, respectively, trunk region). In the head/neck region the effect of weight restriction is less than in for scans of the trunk (−1.3% and −0.2%, respectively); the most prominent changes resulted from excluding scanners with less than 10 patient cases (−5%), and equally weighting scanners rather than cases (−3%).
Conclusion: For adult CT examinations (different to a paediatric survey), quite simple evaluation strategies yield results very comparable to those from sophisticated strategies.

Introduction

In 1996 the International Commission on Radiological Protection introduced the concept of diagnostic reference levels (DRLs) in ICRP Publications 60 and 73 [1–3]. The ICRP recommended choosing "the initial values as a percentile point of the observed distribution of doses to patients". No further suggestions how to define DRLs were given. The European Guidelines for Quality Criteria for Computed Tomography [4] propose to derive DRLs from surveys that take variations between institutions into account. As an example the DRLs of the UK derived from distributions across institutions were presented [5]. In this study the 3rd quartile values from the dose distributions are calculated as suggestions for DRLs.

DRLs are defined for patients with standard size. However, a correlation of dose and patient size can usually be anticipated [6] if protocols are adapted to the patients. European Guidelines on Quality Criteria for Diagnostic Radiographic Images [7] advise to use dose data from patients of approximately "standard size" with a weight of 70 ± 3 kg. If there are not enough patients within this limit one can get a reasonable idea of the typical patient dose by using the average dose from a sample of at least 10 patients [8].

Checks of compliance (with DRLs) are usually regulated by national standards; [9], e.g., suggests to restrict the dose estimator data to patients between 50 and 90 kg to represent the standard-sized patient.

To update the Austrian DRLs, regression analysis as described here has been used. However, for defining the current DRLs in 2001 a very simple pooled data approach with weight banding centered at 70 kg had been applied. This type of evaluation has the advantage of being simple and straight forward, but sacrifices data collected from patient outside of the weight band, and might be biased if reported case numbers from CT centers do not reflect their relative examination frequencies properly. These issues are addressed in this evaluation attempting to systematically quantify the differences in the results (quartiles) for different approaches. This has been the motivation for this work.

* Corresponding author. Tel.: +43 1 40400 1713.
E-mail address: peter.homolka@meduniwien.ac.at (P. Homolka).

1120-1797/$ – see front matter
http://dx.doi.org/10.1016/j.ejmp.2013.01.001

Material and methods

Data

To evaluate different methods to define or update DRLs for CT examinations of adults from dose survey data, data from a nationwide CT dose study in Austria was used. This data has been collected between February 2009 and July 2010 and consists of scan data (DLPs, CT specifications, examination type to name the most important) and corresponding patient data (size and weight) of over 10,000 standard CT scans [10]. In this study an approach to define DRLs for medical examination types instead of body regions was adopted.

In order to compare different evaluation strategies used to calculate quartiles and define DRLs from their values, examinations for which ample patient dose data was available were used. In Table 1 the examinations and the case numbers are shown together the number of scanners from which these data originated. The last two columns provide the number of cases from scanners with 10 or more cases per examination that could be used for regression analysis. For this type of data evaluation both, a minimum number of cases, and a minimum number of scanners, are necessary.

Defining the standard patient

DRLs represent a dose estimator for the "standard patient" normally defined as a person with a weight of 70 kg ± 5 or ±10 kg, respectively. Although this weight represented the average x-ray patient nicely approximately 10 years ago, the average CT patient in Austria has gained additional weight over the last 10 years. In this survey the standard patient was found as a person with 75.6 kg rather than 70 (median 75.0 kg, mean 75.6 kg; sample size 10.385 patients scanned with 45 CT scanners distributed over Austria) compared to an average patient weight from the previous (2001) CT dose study of 70.8 kg. Hence, a body weight of 75.6 kg has been used as the standard patient size in regression analysis to simplify compliance checks with the DRLs.

Methods for data evaluation

As basis for the DRLs the 3rd quartiles of the dose distributions were adopted [8,11–16]. To calculate the third quartiles from the DLP distributions, the following strategies have been applied and compared:

- No correction or omission of data at all (despite data failing plausibility or integrity checks)All patient data included regardless of patient weight or CT scanner
- Weight restriction method:

DLP data from patients within a weight interval centered at 70 or 75.6 kg, respectively, and a width of ±20 kg were used for the calculation of the 3rd quartiles of the DLPs. In this method every data set has equal statistic weight, which means that CT scanners having provided more data have more influence on the result than CT scanners with fewer cases, and are therefore overrepresented. It should be noted that the assumption, that CT scanners with more data available represent scanners with higher patient frequency, did not apply in general.

- Regression method:

From the DLP data of an examination type and CT scanner a representative value ("typical dose") for the standard patient was calculated through regression analysis. Quartiles were then calculated from these representative DLP values as described in the following section.

Regression analysis

Regression

If an exponential relation between weight and DLP for a given scanner can be assumed, an exponential function can be fitted using an iterative least square method:

$$\mathrm{DLP}(w) = p_0 * e^{p_1 * w} \quad (1)$$

with the two parameters p_0 and p_1, and the patient weight w. The DLP of the standard patient is calculated using the regression curve as DLP(75.6) corresponding to the DLP at the typical patient's weight. Also 95% confidence intervals (CI) were calculated. However, especially if protocols are not adapted to the patients' physique as often seen especially in head scans, the attempt to

Table 1
Numbers of cases and CT scanners providing data.

Examination type	All		70 ± 20 kg		75.6 ± 20 kg		≥10 cases per CT	
	Cases	CTs	Cases	CTs	Cases	CTs	Cases	CTs
Abdomen								
Staging/metastases w/o chest	536	53	435	53	436	53	400	22
Staging/metastases w/chest	800	52	664	51	650	50	707	33
Acute abdomen	486	47	403	46	372	47	398	26
Liver lesion	306	41	234	41	236	40	213	15
Renal tumor	278	42	218	41	220	40	172	11
Lumbar spine								
Kidney stone search	367	46	282	43	282	43	268	19
Chest								
Staging/metastases chest	342	49	277	48	263	47	228	18
Inflammation	364	50	310	50	301	50	229	16
Exclusion of lesion/screening	322	45	274	45	264	43	197	14
Pulmonary embolism	422	47	344	46	339	46	343	23
Head/neck								
Trauma/bleeding (brain)	737	51	618	50	574	49	667	32
Mass/metastases (brain)	514	48	435	47	420	47	426	23
Stroke	451	41	396	39	378	41	361	20
Cervical spine	173	32	156	32	148	32	109	10
Paranasal sinuses	514	49	459	47	413	47	423	26
Middle-, inner ear, petrous bone	196	33	165	31	161	33	129	11