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Original research article

Establishment of national diagnostic reference levels (DRLs) for radiotherapy localisation computer tomography of the head and neck

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ABSTRACT

Aim: The aim of this research is to establish if variation exists in the dose delivered for head and neck (HN) localisation computed tomography (CT) imaging in radiation therapy (RT); to propose a national diagnostic reference levels (DRLs) for this procedure and to make a comparison between the national DRL and a DRL of a European sample.

Background: CT has become an indispensable tool in radiotherapy (RT) treatment planning. It is a requirement of legislation in many countries that doses of ionising radiation for medical exposures be kept 'As Low As Reasonably Achievable'. There are currently no dose guidelines for RT localisation CT of the HN.

Materials and methods: All RT departments in Ireland and a sample of European departments were surveyed. Dose data on CT dose length product (DLP); dose index volume (CTDIvol); current time product; tube voltage and scan length was acquired for ten average-sized HN patients from each department. DRLs were proposed for DLP and CTDIvol using the rounded 75th percentile of the distribution of the means.

Results: 42% of Irish departments and one European department completed the survey. Significant variation was found in the mean DLP, CTDIvol and scan lengths across the Irish departments. The proposed Irish DRL is 882 mGy cm and 21 mGy and the European department DRL is 816 mGy cm and 21 mGy, for DLP and CTDIvol, respectively.

Conclusions: Variation exists in doses used for HN RT localisation CT. DRLs have been proposed for comparison purposes with the aim of dose optimisation.

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1. Background

Computed tomography (CT) has become an indispensable tool in oncological imaging. Head and neck (HN) radiotherapy (RT) patients are reliant on this method of imaging for treatment planning, treatment response assessment and follow up. A significant number of HN patients are now treated using intensity modulated techniques; this necessitates the need for high quality CT images to aid accurate tumour and normal tissue delineation.

CT is associated with high radiation doses and subsequent risk of carcinogenesis.[1] A National Cancer Institute study estimates that 29,000 excess cancer cases could result from patients exposed to CT scans in the United States in 2007 alone.[2] Cumulative radiation exposure in excess of 75 mSv has been estimated to increase cancer mortality in the general population by 7.3%,[3] this necessities that, where possible, CT dose should be kept to a minimum.[4,5] The CT dose when compared to the therapeutic treatment is minute; however, it is not insignificant when considered in the linear-no-threshold model. RT localisation CT scans fall under the 'non-therapeutic' dose category and, as such, are governed by the 'As Low As Reasonably Achievable' (ALARA) principle.

The International Commission of Radiation Protection (ICRP),[6] the International Atomic Energy Agency (IAEA)[7] and The European Council Directive 13/59 EURATOM[8] established legislation to protect patients against the dangers of excessive ionising radiation from medical exposures through adherence to the ALARA principle. This Directive is based on the stochastic effect of radiation; these occur without a dose threshold, and increase in probability with increasing dose.[9] The ICRP introduced the use of diagnostic reference levels (DRL) for imaging procedure. DRL is defined as a level intended to identify situations where the patient dose or administered activity is unusually high.[10] The objective of a DRL is to help avoid excessive radiation dose that does not contribute additional clinical information. While DRLs are not mandatory in all countries, their use is endorsed by many professional and regulatory organisations, including the ICRP, The Australian Radiation Protection and Nuclear Safety Agency; American College of Radiology, American Association of Physicists in Medicine, UK Health Protection Agency and IAEA.

Diagnostic DRLs exist in many countries and there is some literature investigating DRLs in RT thorax and breast imaging[11,12] but no attempts have been made to introduce dose audit in HN RT CT imaging. Different scanning volumes, protocols and image quality requirements between diagnostic and RT CT do not support the use of diagnostic imaging (DI) DRLs in RT practice.[13]

The localisation CT scan range encompasses the tumour volume, with a volume of normal tissue superiorly and inferiorly. HN region contains many Class I & II radiosensitive organs including the brainstem, hypothalamus, optic chiasm, salivary and endocrine glands[13]; thus, it is an important anatomical region in which to optimise dose.

European guidelines set DRLs at the 75th percentile of the distribution of mean doses based on a representative sample of patients from a broad user base.[14] This use of the third quartile is also based on previous work in DI.[7,15,16] The ICRP recommend that DRLs are based on relevant local, regional or national data and that national DRLs should be compared to international DRLs to ensure that CT practice is optimised and standardised.

2. Aim

The purpose of this research is to investigate CT dose variation between RT departments in Ireland, to propose a national DRL for CT HN cancer localisation in RT and to compare this DRL to a sample of European departments. This DRL provides a basis for dose optimisation with the potential for dose reduction.

3. Materials and methods

Ethics approval was granted by the Faculty of Health Sciences Research Committee of Trinity College Dublin. The methodology used in this research was based on the guidelines from the ICRP[6] and European guidelines.[14] All radiation therapy departments in Ireland ($n = 12$) and a European sample ($n = 25$) were invited to participate in an anonymised dose audit survey of 10 average-sized HN patients (excluding neurological patients) over a six week period.

A sample of 10 patients is the minimum number recommended by European guidelines[14] and this figure is based on previous work that established diagnostic CT dose reference levels in Ireland.[17]

In diagnostic studies, DRLs are proposed based on two primary dosimetry metrics: CT dose index volume (CTDIvol) and dose length product (DLP).[7,15,16] CTDIvol specifies the radiation intensity used to perform a specific CT examination. For a given scanner and a set of acquisition parameters, the CTDIvol is fixed and independent of patient size and scan length. Although it is not a direct gauge of patient dose it allows users to compare different scanners and scan protocols.[18] DLP is the product of CTDIvol and scan length and can be used as an indicator of patient dose from a CT scan.

Each participating department was asked to record general information on the CT scanner made and model. Specific information was sought for each scan; disease site, CTDIvol, DLP, peak tube potential (kVp), effective current-time product (mAs), scan length (mm); anatomical scanning range, acquisition slice thickness and if automatic exposure control (AEC) was used.

Data analysis was performed using SPSS v. 20.0 (PASW, Chicago, IL). The proposed DRL was based on the rounded 75th percentile of the CTDIvol and DLP for each scan recorded by the department. The European data was used to calculate the DLP for comparison purposes only. Two sample t-tests were carried out to assess whether the mean DLP, CTDIvol and mean scan length differed significantly between departments. A p value of $p < 0.05$ was considered statistically significant.

4. Results

Surveys were returned by five of the twelve Irish RT departments, representing 42% of the national departments. One Irish department that failed to return the survey indicated