ASSESSMENT OF DOSE INDICATORS FOR CT LOCALIZATION PROCEDURES IN RADIATION THERAPY AT UNIVERSITY HOSPITAL RIJEKA

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AN ASSESSMENT OF DOSE INDICATORS FOR COMPUTED TOMOGRAPHY LOCALIZATION PROCEDURES IN RADIATION THERAPY AT THE UNIVERSITY HOSPITAL RIJEKA

by

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The computed tomography has become a standard tool in radiation therapy treatment planning. Additionally, there is a growing awareness of the dose delivered to the part of the body outside the target volume. The ionizing radiation carries a stochastic risk of malignancy, therefore, the doses should be kept as low as reasonably achievable in order to provide an adequate information needed for the radiotherapy planning. The objective of this work was to set up the initial diagnostic reference levels and correlate to the image quality that would be used in the future optimization of localization scans. To quantify the doses from computed tomography localization scans at the University Hospital Rijeka, local diagnostic reference levels were established for five most common procedures of different anatomical regions; head, head and neck, pelvis, breast and thorax. The Computed Tomography Dose Index volumetric and the Dose-Length Product were used as dose indicators and scanning parameters were also recorded. The image quality assessment was performed for each set of images. The results were compared to the seldom published data in order to compare the clinical practice. The image quality for almost all of the body regions are scored as acceptable in average but require improvement. It is shown that the optimization of radiotherapy protocols is required. Therefore, these results will be used as a guideline for that process. The establishment of the national diagnostic reference levels for computed tomography localization procedures in radiation therapy is the next step and is currently an ongoing process.

Key words: computed tomography, radiation therapy, optimization

INTRODUCTION

The computed tomography (CT) is an extremely useful tool in medical practice and consequently the frequency of CT examination is increasing over the world [1, 2]. The optimization of diagnostic CT protocols at the University Hospital Rijeka (UH Rijeka) was performed throughout the period between 2016 and 2017. An excellent progress within this process has led us to expand our field of work to other applications of CT scanning, such as the radiotherapy. The CT has become a standard tool in radiation therapy (RT) treatment planning. Namely, it is well known that the use of advanced radiation therapy techniques increased the survival rate of oncology patients but also increased possibility by radiation induced secondary malignoma. Some might argue that the CT doses are negligible compared to the therapeutic doses. However, there is a growing awareness of the dose delivered to the part of the body outside the target volume [3-6]. The CT is associated with relatively high radiation doses, causing concerns regarding the risk of carcinogenesis [7, 8]. The doses for any medical exposure should be kept as low as reasonably achievable in order to provide the adequate diagnostic information, in this case the information needed for the radiotherapy planning. The quality of CT simulation imaging information provide more accurate delineation of the target volumes and organs at risk, so called contouring, which plays a critical role for the accurate radiation treatment planning.

The diagnostic reference level (DRL) has proven to be an effective tool that helps in the optimization of diagnostic and interventional procedures. The DRL are not intended for the use in radiation therapy, but they should be considered for imaging the treatment planning and patient set-up verification in radiotherapy [9]. The objective of this work was to set up the initial DRL and correlate to the image quality that would be used in the future optimization of localization scans.

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MATERIALS AND METHODS

Procedures

To quantify the doses from the CT localization scans at the UH Rijeka, local DRL values were established for five most common procedures of different anatomical regions; head, head and neck, pelvis, breast and thorax. Breast scans refer only to the patients receiving the tangential breast radiotherapy. The post-mastectomy patients and those patients receiving the radiotherapy to the supraclavicular fossa were excluded. A retrospective analysis was performed on Somatom Sensation Open (Siemens Healthineers, Erlangen, Germany), a 16-slice CT simulator with a 80 cm bore installed at the radiotherapy department. The scanner is used exclusively for the radiotherapy planning.

The scanning protocols that were in the scope of this investigation are summarized in tab. 1.

All localization scans were performed using a spiral acquisition mode with the nominal single collimation width of 1.2 mm and the total nominal collimation width of 28.8 mm. Scanning region margins are anatomically clearly defined in the radiotherapy protocol for the given indication. The head is scanned from the top of the skull to the lower margin of the third thoracic vertebra. The head and the neck are scanned from the top of the skull to the lower margin of the fifth thoracic vertebra. The pelvis is scanned from the L3-L4 intervertebral disc space to the femur neck. The breast is scanned from the lower margin of the mandible to the second lumbar vertebra. The thorax is scanned from the upper margin of the larynx to the second lumbar vertebra.

Dose assessment

The data were collected using the dose tracking software, the CARE Analytics (Siemens Healthineers, Erlangen, Germany). The CARE Analytics is a non-medical, free-of-charge computational tool. The dose received by each individual patient is recorded in the DICOM Radiation Dose Structured Report. The relevant data in these files comprises information such as $CTDI_{vol}$ (Computed Tomography Dose Index volumetric), DLP (Dose Length Product), scan length, collimation, tube voltage, *etc*. The relevant information is presented in a table format for further analysis, *e. g.*, statistical reports of dose data and related parameters.

The $CTDI_{vol}$ and DLP were used as dose indicators thus scanning parameters were also recorded. Prior to the study, the verification of the displayed $CTDI_{vol}$ was made. The CTDI was measured using the CT dosimetry phantom (Pro Project, Poland) and calibrated Piranha multimeter along with the CT ionization chamber (RTI Electronics, Sweden). The measured $CTDI_{vol}$ was in good agreement with the displayed values with the discrepancy of 6 %. The scout image was omitted from data collection.

Image quality assessment

Since the aim of this study was to start the optimization process, the image quality assessment was performed for each set of images. For each body region, two radiation oncologists were asked to score the image quality based on the given image quality criteria using a four-level scale; 1 – not acceptable for contouring, 2 – acceptable for contouring, but requires improvement, 3 – fully acceptable for contouring and 4 – image quality more than needed for contouring. The quantitative quality control measurements are performed regularly on this equipment in accordance with the quality control protocol and the results are within the acceptability criteria.

DRL calculations

The median scan length, the DLP and the $CTDI_{vol}$ and the image quality score were calculated for each acquisition protocol. It is recommended that median values of the DRL quantity for medical imaging procedures for a specific X-ray room should be compared with the DRL values to identify whether the data for the location are substantially higher or lower than those that might be anticipated [9]. The median was also used for scanner average as a method for dealing with the lack of weight information.

RESULTS

The, median values were calculated for $CTDI_{vol}$, DLP and scan length for each protocol (tab. 2).

Table 2. Median values for $CTDI_{vol}$, DLP and scan length at UH Rijeka

Protocol	$CTDI_{vol}$ [mGy]	DLP [mGycm]	Scan length [mm]
RT Head	60	1365	228
RT H&N	15	690	461
RT Pelvis	17	802	480
RT Breast	7	287	409
RT Thorax	9	352	403

Table 1. Scanning parameters of the localization protocols

Protocol	Acquisition type	Voltage [kV]	Reference [mAs]	Collimation [N × mm]	AEC	Rotation time [s]	Pitch	Slice thickness [mm]	Reconstruction kernel
RT Head	Helical	120	320	24 1.2	off	1	0.55	2	H31s
RT H&N	Helical	120	120	24 1.2	on	1	0.9	3	B31s
RT Pelvis	Helical	120	190	24 1.2	on	1	1.2	3	B30s
RT Breast	Helical	120	95	24 1.2	on	1	1.2	3	B31s
RT Thorax	Helical	120	95	24 1.2	on	1	1.2	4	B31s

The median $CTDI_{vol}$ were calculated to be 60 mGy, 15 mGy, 17 mGy, 7 mGy, and 9 mGy for head, head and neck, pelvis, breast and thorax planning regions, respectively (tab. 2). A comparison of median CTDIvol of the UH Rijeka with published data [3-6] is presented in fig. 1.

The median DLP were calculated to be 1365 mGycm, 690 mGycm, 802 mGycm, 287 mGycm and 352 mGycm for head, head and neck, pelvis, breast and thorax planning regions, respectively (tab. 2). A comparison of median DLP of the UH Rijeka with published data is presented in fig. 2.

The median scan lengths were calculated to be 228 mm, 461 mm, 480 mm, 409 mm, and 403 mm for head, head and neck, pelvis, breast and thorax planning regions, respectively (tab. 2). A comparison of median scan length of the UH Rijeka with published data is presented in fig. 3.

The medians of image quality scores for each region are given in tab. 3. Figure 4 represents the comparison of the scores with the ideal score 3 = fully acceptable for contouring.

DISCUSSION

The national DRL for radiotherapy planning CT scans do not exist at this moment in Croatia or region. Even though the situation is not much better for the diagnostic DRLs also, some assessments have been performed over the past few years [10]. The results were

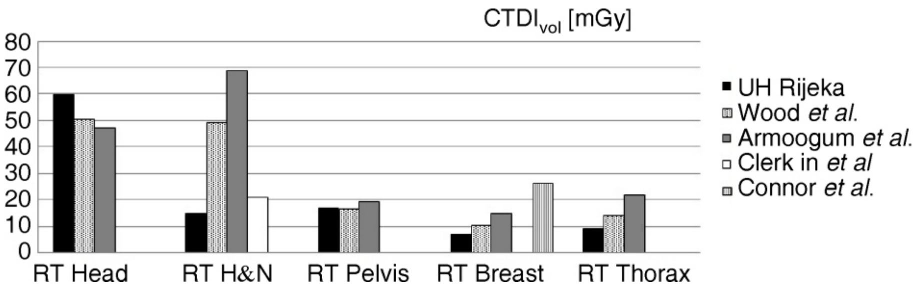

Figure 1. A comparison of median $CTDI_{vol}$ of the UH Rijeka with published data

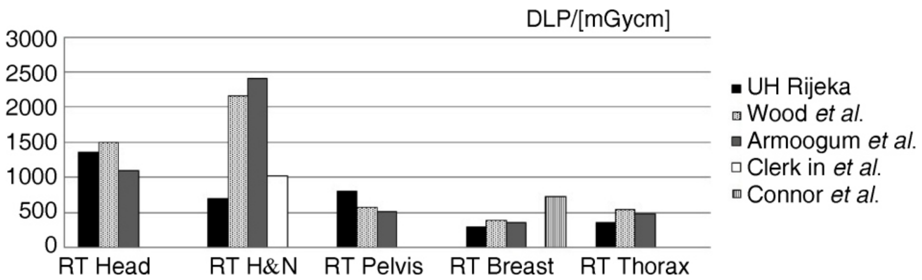

Figure 2. A comparison of median DLP of UH Rijeka with published data

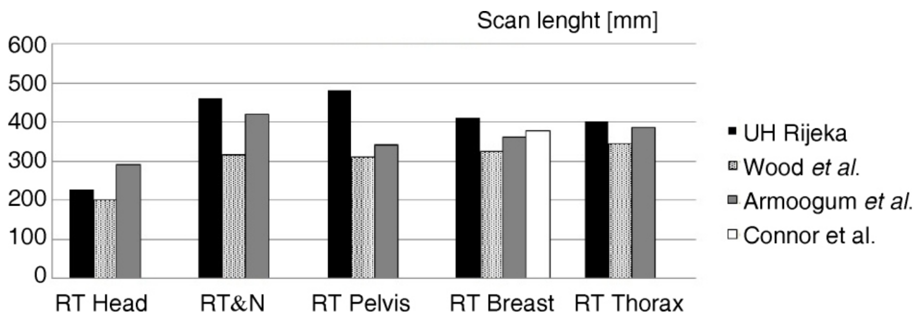

Figure 3. A comparison of median scan length of UH Rijeka with published data

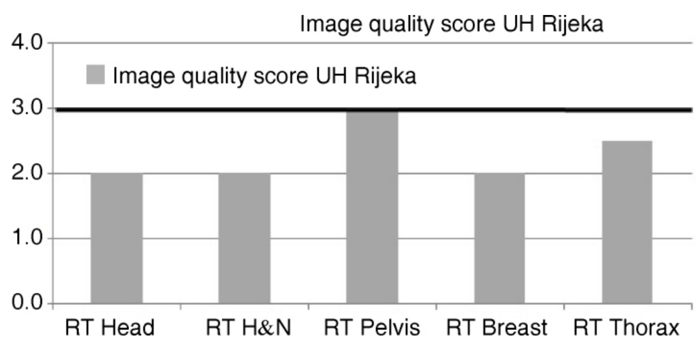

Figure 4. The comparison of the scores with the ideal score 3 – fully acceptable for contouring

Table 3. Median image quality scores for each anatomical region

Protocol	Image quality score
RT Head	2.0
RT H&N	2.0
RT Pelvis	3.0
RT Breast	2.0
RT Thorax	2.5

compared to the seldom published data in order to compare the clinical practices [3-6]. Two of the published values are the national DRL values and therefore correspond to the 75th percentile of the collected data. One of the published values refers to the single center audit and is given as the mean of the collected data. The comparison of the results shows great variation in imaging techniques, dose indicators as well as the scan region length.

The localization head protocol at the UH Rijeka appears to have the highest $CTDI_{vol}$ and DLP value within the published values. However, the scan length is not the highest which indicates that the scanner output parameters should be adjusted to decrease the dose to the patient. The degradation of the image quality is to be compensated with the parameters that do not influence the dose on this type of scanner, such as the reconstruction kernel. Also, this is the only protocol that does not use the dose modulation. Therefore, it is one of the options to consider in order to optimize the protocol.

On the other hand, the dose indicators for head & neck acquisition protocol are the lowest with the highest value of the scan length. Having in mind that the image quality for this anatomical region is not fully acceptable for contouring, we can conclude that the scanner output should be increased to a level which could ensure the optimal imaging information.

The $CTDI_{vol}$ for pelvis are comparable with other data. However, the DLP and scan length are slightly higher which indicates the revision of margins of the scanning region.

The dose indicators for breast and thorax are quite similar to the other published values with slightly longer regions of scanning. Therefore, same as for head & neck, the scanner output could be slightly increased in order to obtain the images of higher quality.

The DRL is a level used in medical imaging to indicate whether, in routine conditions, the dose to the patient in a specified radiological procedure for medical imaging is unusually high or unusually low for that procedure. However, the application of DRL is not sufficient by itself for the optimisation of protection. The image quality or, more generally, the diagnostic information provided by the examination, including the effects of post-processing, must also be evaluated [9].

The image quality for almost all of the body regions at Radiotherapy Department of the UH Rijeka are scored as acceptable but require improvement. This clearly indicates that the scanning and the reconstruction parameters need to be revised to achieve the optimal image quality. However, the image quality score can be influenced by the monitor performance and ambient light in the contouring room. These issues were not the scope of this study but should be thoroughly investigated. Although there are different qualitative and quantitative methodologies to describe the image quality [11], we decided to apply the subjective image quality scoring method which proved to be sufficient for the overall investigation of practice. The objective of this study was acceptability assessment of the image quality performed by the radiation oncologist. There was no intention to accurately assess or to accurately compare images on image quality scale [12]. The detailed analysis of the reasons for poor image quality was not conducted and will be performed in the next step, which is the optimization of the simulation protocols.

There are, however, some limitations to this study. A relatively small sample size has motivated us to broaden our work to the national level. Also, the image quality scoring was performed in uncontrolled conditions in the contouring rooms in terms of ambient light which can clearly affect the image quality score.

CONCLUSIONS

The modern radiotherapy techniques made it possible to deliver the increased dose to the target volume. However, there is a strong focus on minimizing the dose to the surrounding tissues. A lot of effort has been made to ensure more precise calculation of the treatment planning systems [13]. These modern techniques often require repeated CT imaging for re-planning during the therapy course. Therefore, the attention must also be paid to the optimization of CT simulation protocols. Finding the optimal dose for achieving the imaging goal is in the focus of many research groups in the field of radiotherapy imaging [14, 15].

At this moment, almost all of the simulation scanning protocols at UH Rijeka are the ones given by the manufacturer and no optimization has been done so far. If certain parameters are to be modified one should keep in mind to make the same modification within the treatment planning system also, since the dose calculation depends on the CT data input. The results of this investigation were used to set up the initial DRL values in radiotherapy at the UH Rijeka. Since the median image quality score was lower than 3 for most of the protocols in the scope, these results cannot be considered as local DRL values. However, it is shown that the optimization of RT protocols is required, therefore these results will be used as a guideline tool for that process. The establishment of the national DRL for CT localization procedures in radiation therapy in Croatia is the next step and is currently an ongoing process.

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AUTHORS' CONTRIBUTIONS

The idea was initiated by A. Diklić. The data collection and the statistical analysis was carried out by A. Diklić and D. Šegota. S. Jurković, and I. B. Lovasić enabled the cooperation between the Medical Physics and the Radiotherapy Department. I. Belac-Lovasić organised the image quality scoring and provided access to radiotherapy data. S. Jurković led the presented research and supervised its development that resulted in this paper. All the authors participated in the discussion of the presented results.

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ПРОЦЕНА ДОЗНИХ ИНДИКАТОРА У КОМПЈУТЕРИЗОВАНОМ ТОМОГРАФИЈОМ ЛОКАЛИЗАЦИОНИМ ПОСТУПЦИМА ТЕРАПИЈЕ ЗРАЧЕЊЕМ У УНИВЕРЗИТЕТСКОЈ БОЛНИЦИ У РИЈЕЦИ

Осликавање компјутеризованом томографијом представља стандард у аквизицији података нужних за квалитетну имплементацију напредних техника терапије зрачењем. Уз то, све више расте свест о предатој дози на део тела изван циљаног волумена. Јонизујуће зрачење носи стохастички ризик индуковања појаве малигних тумора, стога доза јонизујућег зрачења треба да буде толико ниска колико је то разумно могуће, како би се осигурале визуелне информације довољно доброг квалитета потребне за планирање радиотерапије. Циљ рада је да се одреде почетни дијагностички референтни нивои и њихова корелација с квалитетом слике. Успостављени референтни нивои користиће се за будућу оптимизацију процедура у сврху планирања радиотерапије. Да би се квантификовала доза предата приликом појединe процедуре компјутеризованом томографијом, које се користе у Клиничком болничком центру Ријека, успостављене су локални дијагностички референтни нивои за пет најчешћих поступака различитих анатомских области: главе, главе и врата, карлице, дојке и грудног коша. Као индикатори дозе коришћени су волуметријски дозни индекс компјутеризоване томографије и производ дозе и дужине скенирања, а бележени су и параметри скенирања. За сваки сет слика извршена је процена квалитета слике. Резултати су упоређени с доступним подацима објављеним у литератури како би се упоредила клиничка пракса. Квалитет слике за готово сва подручја тела у просеку је оцењена прихватљивом, али захтева побољшање. Показано је да је потребна оптимизација процедура које се користе у сврху планирања радиотерапије и самих радиотерапијских протокола, стога ће ти резултати бити коришћени као смерница за извођење тог процеса. Успостављање националних дијагностичких референтних нивоа за симулацију компјутеризованом томографијом у терапији зрачењем следећи је корак и тренутно је у поступку.

Кључне речи: компјутеризована томографија, терапија зрачењем, оптимизација