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COMPARISON OF IMAGE QUALITY AND DIFFERENT RADIATION DOSES IN COMPUTERIZED TOMOGRAPHIC DIAGNOSTICS

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Objective: The aim of this paper was to evaluate standard protocols for certain types of CT examinations, as well as to modify it in terms of reducing the radiation dose on the patient while maintaining the diagnostic image quality, which gives this work an important practical significance.

Methods: The study was conducted at the Clinic of Radiology and Nuclear Medicine at Tuzla University Clinical Center, in the period from June to October 2018. The study was carried out in 2 phases: in the first phase, the standard protocol for the region of the body being recorded was used, and in the second phase CT examinations were performed according to the modified protocol (by changing the parameters of the mAs and kV values), with the minimum requirements regarding image quality. Based on dosimetry indicators, the effective dose and radiation risk for patients in both phases was assessed. The image quality for each patient was evaluated using a three-stage visualization scale for each parameter of the anatomical region. The total number of patients involved in the study was 312.

Results: The results showed that with optimum protocol selection in terms of exposure parameters (by increasing and decreasing the value of mAs and kV), it is possible to significantly decrease the dose of radiation in the head examination by 5%, in the chest examination by 2%, in the chest and upper abdomen examination by 6%, and when examining the abdomen by 8%.

Conclusion: By applying standard imaging protocols, the quality of image necessary for adequate radiological interpretation is achieved, hence a higher radiation dose than necessary. With optimum protocol selection in terms of exposure parameters, it is possible to significantly reduce the dose of radiation, with a satisfactory quality of the diagnostic image necessary for further radiological interpretation.

INTRODUCTION

AComputerized tomography (CT) is one of the most important diagnostic modalities. In the total number of radiological examinations, CT makes up to 5-10%, but its contribution to the total received dose for the population is greater than 50%. Ionizing radiation, which is used daily for screening patients around the world, records a growing trend (1). Medical use of radiation makes up 98% of the population's contribution from all artificial sources and accounts for 20% of the total population exposure. More than 3600 million diagnostic radiological examinations are being carried out annually worldwide, 37 million nuclear medical procedures are conducted and 7.5 million radiotherapy treatments (2). A significant change in exposure to ionizing radiation was the result of an increase in medical exposure (3), (4). An increasing number of medical procedures, the frequency of CT scans and the dose of ionizing radiation after examination at an annual level have an important impact on the overall dose of radiation for the population. The introduction of spiral and multilayer scanning has reduced the scanning time. Furthermore, it is possible to perform multiple examinations at a given time, expand the region of interest for scanning, and introduce new techniques and examinations (5). The ionizing radiation protection system has different forms, depending on the type of radiation source and the nature of human activities that result in exposure to ionizing radiation. It is particularly important to reduce unnecessary exposure, which is achieved by applying the basic principles of radiation protection (6): justification of the examination: referral of patients (based on different criteria) and feasibility assessment; optimization: equipment and daily monitoring.

As CT is classified as a device that delivers large radiation doses, it is necessary to comply with the ALARA (As Low As Reasonably Achievable) principle. The radiation dose for the patient should be as low as reasonably possible without damaging the diagnostic information, or the quality of pictures (7). The literature lists a number of strategies that can be applied to optimize multidetector CT-MDCT overview, and the first strategy we can use is the choice of protocols and exposure parameters. Ionizing radiation is a strong carcinogen, and cancer belongs to stochastic effects. Since regular CT scans are performed below the deterministic effect threshold, stochastic effects are of a great interest. It should not be forgotten that patients are often referred to repeat CT scans, with a total dose of about 100 mSv. This dose is sufficient to make us talk about an increased likelihood of stochastic effects. The above reasons indicate that it is necessary to reduce the number of unjustified CT exams, which can be achieved by careful analysis of justification both from clinical and dosimetry aspects. There are also significant variations in the radiation dose in CT examination of the same anatomical regions in various hospital establishments. These variations in dosage are the result of several factors: the hardware differences of the CT apparatus, the non-standardized protocols for the CT scan and the variation of anatomical patient composition (BMI). The goal of optimization is to provide a good picture quality with a minimum dose for the patient. Control is achieved by optimizing the parameters that directly and indirectly affect the CT dose (6,8-11).

MATERIALS AND METHODS

The study was conducted at the Clinic of Radiology and Nuclear Medicine at Tuzla University Clinical Center in the period of June 2018 to October 2018. The study, which was conducted in 2 phases (non-optimized phase and optimized screening phase), included adult respondents, both sexes, who were referred to scan certain body parts with multilayer computerized tomography. The total number of patients included in the study was 312. The condition for performing the study was to inform the patients and their signed consent. Factors that led patients to be excluded from the study were patients who did not succumb to a standard protocol radiation dose (dynamic recording) for a particular type of examination, as well as patients who could not agree to this examination (comatose patients, delirious and lack of body mass and height data patients). For each type of CT scan, the minimum quality requirements were defined in advance. Depending on which part was scanned, respondents and their recording parameters were recorded in 4 groups: I group - CT head (Head routine), II group - CT chest (Thorax routine), III group - CT chest and upper abdomen (Thorax and upper abdomen routine), IV group - CT abdomen (Abdomen routine). For all four groups of CT patients, CT recording was performed on two devices of the CT Somaton Sensation 64 Siemens (64 detector lines) and the CT Somaton Sensation 16 Siemens (16 detector lines). In the first phase of the study, standard protocols for a particular type of examination were used, and then the patient dose based on the CTDI and DLP value was calculated, the image quality and relevant quality criteria for each type of examination were evaluated.

In the second phase of the study, the examinees within each group were examined using an individualized and optimized protocol, and at the same time the quality of the image and the dosage was evaluated using the methodology as in the first phase. The purpose of the study was to inform the respondents and their signed consent. Factors to exclude patients from the study were patients who did not succumb to a standard protocol radiation dose (dynamic recording) for a particular type of examination, as well as patients who could not agree to this examination (comatose, delirious-lack of body mass and height data). For each type of CT scan, the minimum quality requirements were defined in advance. The standard CT header recording protocol (Table I.). involves a 120 kV tube voltage and a 380 mAs current strength at CT 64 and 320 mAs at CT 16.

Table I. Overview of the standard protocol for examination of the head, chest, abdomen, chest and upper abdomen in CT 64 and CT 16

Parameter	Head	Thorax	Abdomen	Thorax and upper abdomen
Scout	Lat	AP	AP	AP
Mode	H	H	H	H
Corner gantry	0	0	0	0
Collimation	64 x 0,6 16 x 0,75	64 x 0,6 16 x 0,75	64 x 0,6 16 x 0,75	64 x 0,6 16 x 0,75
Pitch	0,8/ 0,55	1,2/1,15	1,2/0,75	1,2/1,15
U [kV]	120	120	120	120
I [mAs]*	380/320	100/100	160/160	100/100
Trot [s]	1/0,5	0,5/0,5	0,5/0,5	0,5/0,5
Slice width	3 mm	5 mm	5 mm	5 mm

* - the mean value is rounded to the whole number
change in relation to the standard protocol

The standard protocol for CT chest and CT chest and upper abdomen is a 120 kV tube voltage and a current intensity of 100 mAs on the CT 64 and CT 16 apparatus. CT abdomens recorded with the standard protocol on the apparatus CT 64 and CT 16 include a voltage of 120 kV and a current of 160 mAs on both devices. Certain patients were randomly recorded according to the standard protocol, and others were given individual parameter optimization based on their height and weight, respectively BMI. The current intensity increased or decreased by up to 40 mAs, and the voltage of the pipe increased or decreased by 20 kV (Table II.).

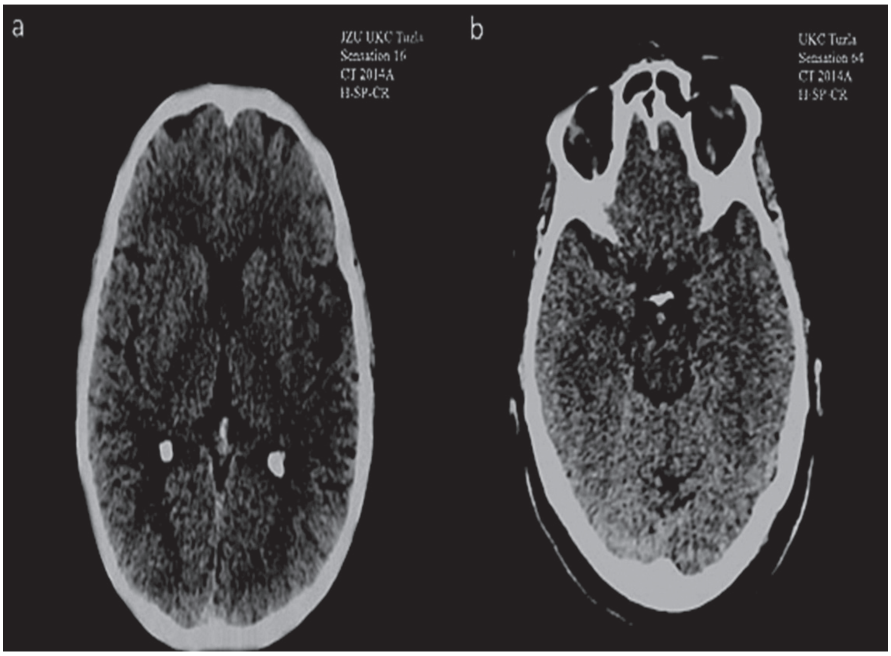
Table II. Tabular view of the optimized protocol for the examinations of the head, chest, abdomen, chest and upper abdomen in CT 64 and CT 16, the difference in relation to the standard protocol in the voltage and the current of the tube

Parameter	Head	Thorax	Abdomen	Thorax and upper abdomen
U [kV]	100/140	100/140	100/140	100/140
I [mAs]*	40;20 < 40;20 >	40;20 < 40;20 >	40;20 < 40;20 >	40;20 < 40;20 >

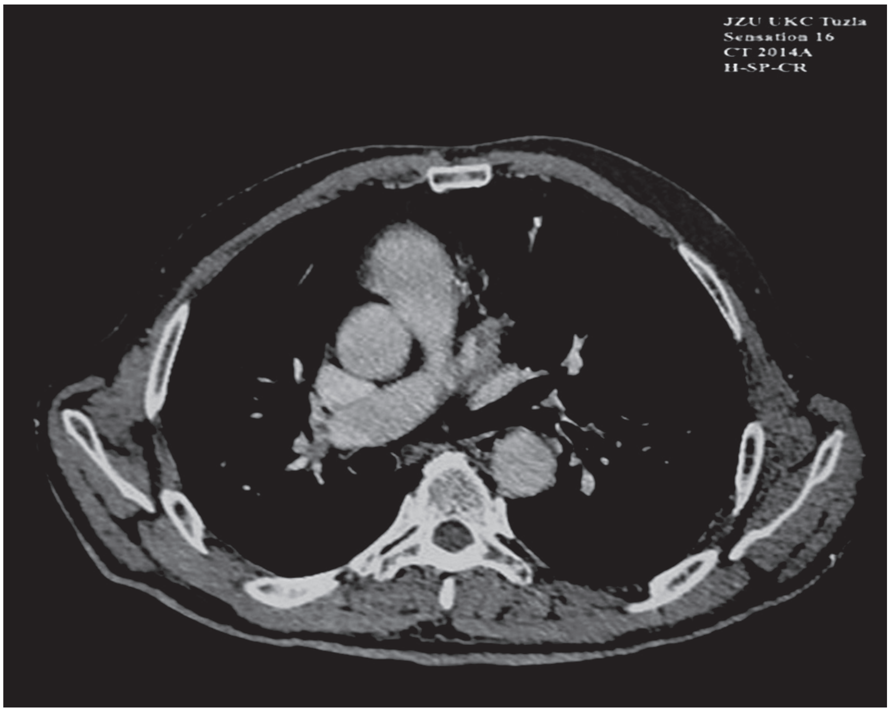
* - the mean value is rounded to the whole number

All patients had their body weight and height measured to calculate the BMI (body mass index) according to the formula for its definition. The BMI values for each patient were necessary in order to adequately carry out the protocol's individualization and modification of the examinations.

The final grade of the image quality of each examination corresponds to the sum of all the parameters estimated by the three-stage scale of visualization. In the assessment of the CT images quality, the criteria that was used is the European Guide for Quality Criteria in CT (12). In order to evaluate whether there is a difference in image quality in a standard and optimized protocol, a subjective method was used where two experienced radiologists performed an image interpretation, which depended on their individual ability to extract structures significant for diagnosis. The images were encrypted and the radiologists did not know whether and for which parameter the optimization was performed, but only evaluated the image quality by score from 1 to 10. It was determined whether there is a statistically significant difference, both per kV, both by mAs and the ratings assigned picture. In relation to kV and mAs, a statistically significant difference in the estimated image quality between groups was not obtained (Picture I.-II.).



Picture I. Cross section of the CT head on the 16-CT scanner: optimization of mAs a) increased by 20, b) increased by 40



Picture II. Cross-section of CT thorax on the 16-CT scanner: optimization of mAs increased by 40

The data collected in this research work were processed by appropriate mathematical-statistical procedures. The analysis was carried out in three steps: testing working hypotheses in terms of whether there is a difference or similarity between the respondents of standard and optimized protocols in relation to image quality, or whether the optimization of the protocol has a negative impact on the quality of the image, whether by applying the standard that the scan protocol receives a significantly higher dose of radiation received by the patient, or by a better image quality compared to respondents of the optimized protocol, as well as the statistical significance of these differences. The most relevant data from the above statistical analysis is presented in tabular or graphical form. Statistical data analysis is performed as part of IBM SPSS Statistic 20 (13).

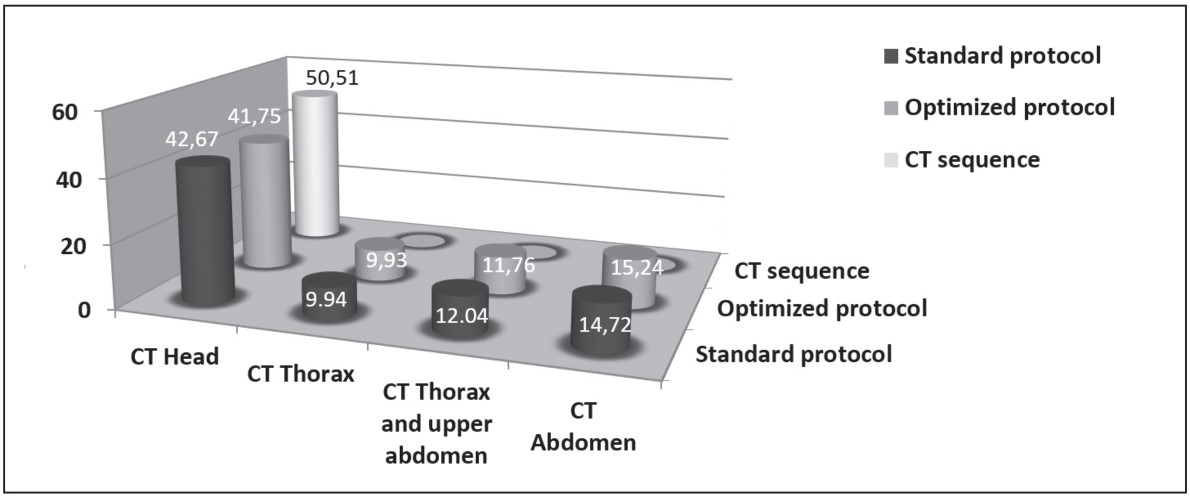


Chart I. A display of the dosage indicator (CTDI) in the survey for all four recording regions

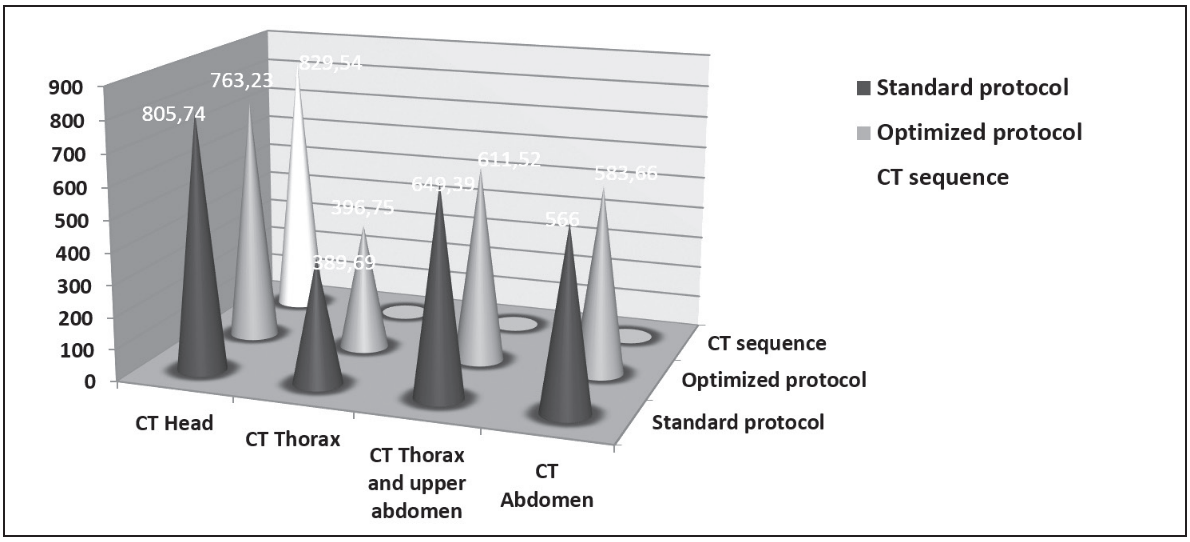


Chart II. Display of the dose indicator (DLP) in the survey for all four recording regions

RESULTS

The study included 312 patients, of which 14 belonged to the sequential scanning group that was not processed in overall statistics, but was compared only with spiral scanning. Out of 298 patients, 169 were scanned by standard protocol and 129 by optimized. In CT 16, 177 patients were scanned; 105 of them with standard protocol, and 72 in optimized. On CT 64, 121 patients were scanned, 64 of them on standard and 57 in optimized protocol. This section outlines the results of this research. The results were designed to determine the existence and significance of the statistical difference between patients who performed the recording in a standard manner compared to the optimized protocol in relation to the given parameters. Descriptive values of the parameters are shown for each region (CT head, CT chest, CT chest and upper abdomen, CT abdomen): the anthropometric characteristics of the subjects (body height, body mass), age of the patients and sex. The existence or absence of a statistically significant difference for each of the parameters in relation to the type of protocol that was made was also determined.

The descriptive values of the parameters that influence the dose of the received radiation, the values of mAs, kV, scanning time, length and FOV for the observed type of examination were shown, and it is determined whether there is a statistically significant difference for the indicated parameters relative to whether the patient was scanned according to standard or optimized protocol. Finally, the same values are also shown for the main dosimetry indicators (CTDIvol and DLP). Finally, the image quality is shown before and after the optimization of the CT scan in relation to FOM, the significance of the difference in the parametric data of the image quality assessment (the sum of the image quality parameters and the final quality score).

By comparing the value of the effective dose in the first and second phase of the study, the reduction of the radiation load for patients after the optimization of the protocol was quantified. The results showed that by optimal protocol selection in terms of exposure parameters (by increasing and decreasing the value of mAs and kV), it is possible to significantly decrease the dose of radiation in the head examination for 5%, in the examination of the chest by 2%, in chest and upper abdomen examination by 6%, and in abdomen examination by 8%.

DISCUSSION

Using standard protocols, image quality that is sufficient for adequate radiological interpretation is achieved, and therefore a higher radiation dose than necessary. With optimum protocol selection in terms of exposure parameters, it is possible to significantly reduce the dose of radiation, with a better quality of the diagnostic image necessary for further radiological interpretation. Therefore, when handling and using ionizing radiation we should take into account whether it is actually necessary in the given situation and what is the profit or damage when it is sampled by ionizing radiation. This should be related in particular to the younger population and it is advisable to avoid multiple CT scanning whenever possible or it should be done as rarely as possible or with a break of several months. It should also be considered to introduce radiological cards as part of a medical identity card that records all performed radiological scans and take into account when selecting diagnostic modalities as there are some that do not radiate, such as ultrasound or magnetic resonance. Even a review of an experienced physician who does the diagnosis comes in a less harmful way. Justification and optimization are two principles of radiation protection that need special attention in radiology, not only because of the control of exposure to ionizing radiation, but also because of other aspects of medical work. A patient who has not undergone an undiagnosed radiochemical examination did not onlyavoid unnecessary exposure to radiation, but also avoided unnecessary cost at the expense of staffing and the use of radiological equipment.

Optimization is not only a reduction in the dose of a patient or population in general, but also a rational use of equipment, which extends the equipment's lifespan and decreases the dose the patients receive professionally exposed faces.

The optimization process should be followed by a clear structure of decision making, guidance, records, reporting, control, and auditing. The results obtained should be published and transparent so that they can be used in education and training. The institution that has performed the procedure optimization must prepare a recording protocol that will be accessible to everyone involved in the work process at the Department of Diagnostic Radiology.

CONCLUSION

By applying standard protocols, image quality that is sufficient for adequate radiological interpretation is achieved, and therefore a higher radiation dose than necessary. By optimal protocol selection in terms of exposure parameters (decrease in mAs), head examination (with / without contrast), chest, abdomen, chest and upper abdomen, it is possible to significantly reduce the dose of radiation with a better quality diagnostic image necessary for adequate radiological interpretation of the image. Doses and radiation risks for standard and optimized screening patients were determined. Values for optimized groups are significantly lower than those in standard groups, and the recommendation of this study is to optimize standard protocols for chest examinations and multiphase abdominal examination in everyday radiological practice to the limit of this study, with few exceptions. For examination of the head without contrast and contrast, it is necessary to pay particular attention to the clinical condition of the patient and the potential pathological substrate of the brain parenchyma, because both aspects can play a key role in the radiologist's decision for more effective optimization of the protocol. The significance of the results of this study is that patients were randomized, and that a clinical assessment of image quality was done. It was found that there is a need for individualization of CT scan protocols according to the diagnosis for obtaining valid diagnostic information (especially for repeated examinations), and adjustment of scanning parameters to patients by BMI value (the highest significance in CT examination of the abdomen and pelvis). However, the dosage values obtained by optimizing the CT protocol in this study do not represent the lowest possible dose for examinations of certain anatomic regions of the body.

For this reason, the recommendation of this paper is further modification of the CT protocol, taking into account both subjective and objective measurements (quantification of observed parameters), and also with the use of ATCM. The dose of radiation for each patient should be optimized individually and we should bare in mind the parameters that may affect the dose of radiation obtained for the patient, without diminishing the quality of the CT image obtained for further radiological interpretation. Some of the parameters that can be optimized are: the number of series to be reduced, the length of the scan should be as short as possible, pay attention to the use of automatic dose control, anode charge (mAs), anode voltage (kV) that affects image contrast and increased anode voltage should be used only in case of obese patients while children should be exposed to lower voltage values, the use of the appropriate width of the layer, use less collimation for shorter scanning lengths and use longer number of rows of detectors using longer scan scans, use appropriate beam filters, use the appropriate value of the pitch factors, reconstruction filters, the level of curvature, and the window opening should correspond to the requirements of the search that is being performed.

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