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Low dose CT: practices and strategies of radiologists in university hospitals

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PURPOSE
We surveyed the practices and policies of the radiology departments of academic institutions in Turkey regarding the use of low dose CT in daily practice.

MATERIALS AND METHODS
Surveys were mailed electronically to radiology departments of 40 university hospitals. Information gathered included modifications of standard protocols for dose reduction according to body parts being examined or depending on specific patient groups such as children, pregnant, or slim patients.

RESULTS
Thirty-three radiology departments (82%) responded. Twenty-eight (85%) reported that they modify CT scanning parameters in order to reduce the patient dose. Of these, 5 (18%) reported that they always modulate the scan parameters, 10 (36%) often, 11 (39%) sometimes, and 2 (7%) seldom. Reduced dose CT is applied mostly in pediatric and pregnant patients, reported by 93% and 57% of respondents, respectively. The most common body part for the application of low dose CT was chest examination followed by imaging of paranasal sinuses, abdomen, and CT-guided interventions. The most common modification for dose reduction is using low mA, followed by increasing the pitch value.

CONCLUSION
Most respondents are aware of low dose CT, but the frequency of application varies considerably in routine practice. Reduced mA and increased pitch are the most commonly used modifications.

Key words: • tomography, X-ray computed • radiation dosage

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The rapid developments in computed tomography (CT) technology over the last decade and its expanding clinical applications have markedly increased the number of CT examinations performed and the average scanned volume obtained per examination. In the last decade, CT accounted for 5% of radiologic examinations globally, and about one third of the overall medical ionizing radiation exposure (1). The use of CT is steadily increasing, and CT scanning accounts for about 15% of procedures and 75% of the diagnostic radiation dose received by patients in large hospitals (2). Because the CT technique is extensively used in benign diseases as well as in young patients, it is of paramount importance for public health to use the lowest acceptable dose during routine diagnostic imaging. However, contrary to other X-ray based examinations, scanning parameters in CT studies are not uniform for most patients, and large variations in CT practice exist (3, 4). Previous surveys of CT practice and dose show that effective dose for a given CT study may vary by a factor of 40 between departments (5). In the face of rising demand for CT examinations, radiologists should optimize the scan parameters to ensure that the patient dose is kept to a minimum. To reduce the radiation dose, appropriate strategies have been developed to optimize scanning practices based on clinical indications, the age or body size of the patients, and the area being investigated (6). The purpose of this study was to investigate the practices and policies of the radiology departments of the academic institutions regarding the application of low dose CT in routine daily practice.

Materials and methods

In August 2004, we electronically mailed a questionnaire regarding the use of low dose CT in daily practice to 40 radiology departments in Turkey. Emphasis was made to ensure that the questionnaire form be filled by faculty radiologists working directly with CT. Respondents were asked to complete the survey and return it by e-mail, fax, or by regular mail to the authors. The survey was electronically mailed several times more through September-December 2004 to remind and enhance the response rate. Only one response was allowed from each institution. The specific survey questions are shown in Figure. The first two questions asked the type and total number of CT scanners at the respondent's institutions, and the total number of CT examinations performed within the last year. The third question asked whether the respondent's department optimizes the CT scanning parameters in order to reduce the patient dose. Those who answered "no" to this question were directed to the final portion of the survey, which asked the respondents to provide the specific area they are working in radiology and the statement of the name of their hospital or institution. For those respondents who answered "yes" to the third question, subsequent questions gathered information about how

Questionnaire: Practices and Strategies for Low Dose CT
(To be completed by faculty radiologists directly working with CT)

1. Please select the type and indicate the number of CT scanners at your institution. Please check all that apply.

__ Single slice axial CT
__ Spiral (helical) CT
__ Multislice CT
__ Electron beam CT

2. How many CT examinations were performed at your institution in the past year?

3. Do you modify the scanning parameters in order to reduce the patient dose?

__ Yes [__Always __ Often __ Sometimes __ Seldom]
__ No *(Please skip questions 4-6, and go to question 7.)*

4. In which of the following patient populations do you adjust the scanning parameters? Please check all that apply.

__ Pediatric patients
__ Pregnant patients
__ Slim patients (dose adjustment according to weight)
__ Other, please list

5. In which of the following CT examinations do you optimize the scanning parameters? Please check all that apply.

__ Paranasal sinus CT
__ Chest CT
__ Chest HRCT
__ Abdominal CT
__ CT for urinary tract calculi
__ CT colonography
__ CT-guided interventional procedures
__ Other, please list

6. Which of the following modifications do you use for reducing patient dose? Please check all that apply.

__ Reduced mAs
__ Reduced kVp
__ Increased pitch
__ Reduced area of image acquisition in the z-axis
__ Thicker collimation (wider beam collimation)
__ Single-detector helical CT scanner rather than multislice
__ Automatic modulation of tube current (if present)
__ Shielding of radiosensitive organs
__ Avoiding multiphasic CT of the abdomen if not indicated
__ Other, please list

7. Please identify the area (based on the system or modality) you are involved in radiology

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8. Please indicate the name of your hospital or academic institution

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Figure. Questionnaire used in the study.

often and in what kind of patients or CT examinations they perform low dose CT, and the use of dose-reduction strategies. Finally, the respondents were asked to identify the specific area they are working in radiology and the name of their hospital or institution. The total number of licensed CT scanners in Turkey was obtained from the Turkish Atomic Energy Agency.

Results

Out of 40 individuals representing 40 institutions, 33 completed and returned surveys representing an 82% response rate on an institutional basis. There were overall 61 CT scanners in 33 institutions representing the 8.5% of overall 715 CT equipment in Turkey; 14 institutions had one scanner, 13 had two, 3 had three, and 3 had four scanners. The annual number of CT examinations performed in these institutions ranged between 3,000 and 44,369 (mean±standard deviation, 13,988±9,075) resulting in 4,910 examinations per CT scanner. Concerning the type of CT equipment, 13 (39%) of 33 respondents reported to have only single-slice helical CT, 3 (9%) have only multislice CT, and 2 (6%) have only conventional non-helical (axial) CT. Both single-slice helical CT and conventional non-helical CT were present at 7 (21%) institutions, both single-slice helical CT and multislice CT were available at 6 (18%) institutions, and conventional non-helical CT, single-slice helical CT and multislice CT scanners were present at two (6%) departments.

Of the 33 respondents, 28 (85%) reported that they modified CT scanning parameters in order to limit the radiation exposure to patients. Regarding the frequency with which low dose CT modifications are performed, five (18%) of 28 respondents reported that they always optimized the parameters, 10 (36%) often, 11 (39%) sometimes, and 2 (7%) seldom. Concerning specific patient groups, children were the population in whom reduced dose CT was performed most frequently by 26 (93%) of 28 respondents. Sixteen (57%) respondents reported that they modified CT parameters in pregnant patients, and 3 (9%) reported that they did not work with pregnant patients. Low dose CT adjustments for slim patients were reported by 11 (39%) respondents. Chest was the most common body part for the application of low dose CT reported by 19 (68%) of 28 respondents, followed by the paranasal sinuses (n=15, 54%), and abdomen (n=14, 50%). Less than 50% of the respondents reported to perform low dose CT for CT-guided interventions, CT for urolithiasis, high resolution CT of the chest, and CT colonoscopy (Table).

Regarding dose reduction, low mA was the most common technique used by 26 (93%) of the 28 respondents followed by high pitch (*n*=12, 43%) and low peak kilovoltage (*n*=11, 39%). Other modifications including shielding of radiosensitive organs, avoiding multiphasic examination in the abdomen if not necessary, using automatic modulation of tube current, using thicker collimation, reducing the area of *z*-axis coverage were reported by less than 25% of the respondents (Table). Of the nine respondents who had both single-slice helical and multislice CT, only one (11%) chose to use a single-slice helical CT scanner rather than a multislice scanner to limit dose. Three (11%) respondents reported they only applied one modification (reduced mA, *n*=2; reduced kVp, *n*=1), 12 (43%) respondents reported they modified two parameters (reduced mA and reduced kVp, *n*=3; reduced mA and increased pitch, *n*=3; reduced mA and automatic modulation of tube current, *n*=2; reduced mA and shielding, *n*=2; reduced mA and avoiding multiphasic study, *n*=2). The adjustment of three parameters was reported to be applied by eight respondents (29%), four parameters by 3 (11%), five parameters by one (3%), and six parameters by one (3%) respondent.

Concerning the radiologic practices of the 33 respondents who completed the survey, 8 (24%) were chest radiologists, 7 (21%) were abdominal radiologists, and 4 (12%) were head and neck radiologists. Four (12%) respondents worked as chest and abdominal radiologists, four (12%) worked as chest, abdominal, pediatric, and head and neck radiologists, two (6%) worked as chest and head and neck radiologists, two (6%) worked as chest, abdominal, and head and neck radiologists, one (3%) worked as a chest, abdominal, and pediatric radiologist, and another one (3%) worked as a pediatric and abdominal radiologist.

Discussion

The United Nations Scientific Committee on the Effects of Atomic Radiation 1993 Report stated that about 93 million CT examinations were performed worldwide on an annual basis, corresponding to a frequency of 16 examinations per 1,000 inhabitants (7). Introduction of helical and multislice CT significantly increased the use of CT, particularly in vascular, cardiac, and oncologic imaging, that is likely to increase radiation dose further (4, 6). The ionizing radiation associated with CT examination may induce carcinogenesis in the subjects and genetic effects in the offspring of the irradiated individuals due to stochastic effects. According to the recommendation of International Commission on Radiological Protection (ICRP), the risk of cancer induction from CT can be estimated by using the population average risk of 50 induced cancers per mSv of effective dose per million people exposed (8). Therefore, the radiologists must be attentive to their responsibility to maintain an appropriate balance between diagnostic image quality and radiation dose. CT scan parameters should be optimized to keep the radiation exposure as low as reasonably achievable to obtain diagnostic-quality examinations. Several strategies can be applied to reduce the CT radiation dose without significant deterioration in image quality (6). In this survey, we investigated the practices and policies of the radiology departments of the academic institutions in Turkey regarding the use of low dose CT in routine daily practice. Our 82% response rate is higher than the response rates for other surveys that have been published in the radiology literature inquiring practice patterns of radiologists (9, 10).

The mean total number of annual CT examinations performed with 61 scanners in thirty-three institutions was 14,000 (i. e., 4,910 examinations per CT scanner). Multiplying this number with 715 licensed CT equipments, we can roughly estimate that over 3.5 million CT examinations are performed in Turkey on an annual basis, corresponding to a 5% of the population. This rate is in accordance with the frequency of CT examinations in Western world.

Our results show that the majority (85%) of respondents adjust CT parameters to reduce the radiation dose, but only 18% optimize factors in every patient. On the other hand, nearly half (46%) of the respondents using low dose CT manipulate the parameters sometimes or rarely. This result indicates that most of the respondents have concerns about CT radiation dose, but they seldom employ specific low dose CT protocols for routine use.

Table. Practices and strategies of the radiology departments regarding the optimization of radiation dose for CT

Frequency of adjustments of scan parameters for LDCT (n=33)		Adjustments of scan parameters for specific patients (n=28)		Adjustments of scan parameters for body parts being examined (n=28)		Modified scan parameters for LDCT (n=28)	
Always	5 (15%)	Children	26 (93%)	Chest CT	19 (68%)	Reduced mA	26 (93%)
Often	10 (30%)	Pregnant patients	16 (57%)	Paranasal sinus CT	15 (54%)	Increased pitch	12 (43%)
Sometimes	11 (34%)	Slim patients	11 (39%)	Abdominal CT	14 (50%)	Reduced kVp	11 (39%)
Seldom	2 (6%)			CT-guided interventions	12 (43%)	Avoiding multiphasic exam	7 (25%)
Never	5 (15%)			CT for urolithiasis	10 (36%)	Shielding	6 (21%)
				High resolution chest CT	9 (32%)	Automatic modulation of tube current	5 (18%)
				CT colonoscopy	4 (14%)	Thickening collimation	4 (14%)
						Reduced scan length	4 (14%)

LDCT: Low dose CT

Patient-based strategies

Most radiologists in this survey were aware of the radiosensitivity of children, and 93% of respondents reportedly apply reduced dose CT in pediatric population. It has been shown that children, particularly girls, are 10 times more sensitive than adults to the risk of cancer induction from the same effective dose of ionizing radiation, and the effective dose is up to 50% greater when the radiation doses in adult protocols are used in neonates or young children (11-13). Furthermore, previous studies have documented that CT images of acceptable quality can be obtained with 50% less radiation (14-18). However, in a survey among the members of Society for Pediatric Radiology, 15%-40% of respondents were found to be unaware of the techniques used at their institutions, particularly those parameters determining radiation exposure (19). In that survey, a tube current of less than 100 mA was used for helical CT of the chest and abdomen by 33% and 22% of the respondents, respectively, in children 4 years old and younger. However, 14% of the respondents performed chest CT, and 16% performed abdominal CT with tube currents equal to or greater than 200 mA.

With regard to pregnant patients, 57% of respondents in our survey reported that they optimize CT parameters, and 9% reported that they do not work with pregnant patients because of concerns about either radiation dose or use of i. v. contrast material. Winer-Muram et al. have reported that CT angiography for pulmonary embolism is associated with a lower average fetal radiation dose than ventilation–perfusion imaging during all trimesters (17). In a recent survey investigating the strategies among Society of Thoracic Radiology members regarding the use of CT pulmonary angiography in pregnant patients, Schuster et al. reported that only 40% of 43 respondents who perform CT angiography in pregnant patients modify their CT protocols to reduce the dose (9). Although the fetal radiation exposure during CT scan in pregnant patients is well below the 5-rad limit considered safe for fetal exposure, radiologists should be knowledgeable about radiation risks and exposures associated with CT imaging, and weigh up the risks and benefits before proceeding to CT scan. Alternative imaging modalities such as sonography or magnetic resonance imaging should be considered when appropriate.

In contrast to large patients in whom the dose in the center is about half the surface dose, radiation is nearly uniform throughout for thin subjects. For every 4 cm decrease in patient cross-sectional diameter, tube current can be reduced by 50% without affecting the image quality significantly (20). Therefore, children or lighter patients can be scanned with substantially reduced CT dose without compromising image quality. In our survey, adjustment of scanning parameters for slim patients were reported by only 39% of respondents performing low dose CT, indicating that dose optimization based on patient weight and cross-sectional abdominal dimensions is underutilized by radiologists. In a recent study comparing the image quality between standard and 50% reduced dose CT scans in the abdomen, no significant difference was found in patients who weighed less than 81 kg and who had a transverse abdominal diameter of less than 34.5 cm, an anteroposterior diameter of less than 28 cm, a cross-sectional circumference of less than 105 cm, and a cross-sectional area of less than 800 cm^2 (18).

Body part-based strategies

The body part being examined is also important in the optimization of CT scanning parameters. CT radiation dose can be substantially reduced particularly in those structures with a high inherent contrast, such as CT of the chest and paranasal sinuses, CT colonography and CT for urolithiasis. Previous studies have shown that it is possible to reduce CT dose two to ten-fold (140-10 mAs) in chest (21-25) and paranasal sinus imaging (26-29), CT colonoscopy (30), and CT for urinary tract calculi (31-33) without severely compromising the image quality necessary to maintain a diagnostic standard. In our survey, chest was the most common body part in which low dose CT was applied, reported by 68% of respondents, followed by CT of the paranasal sinuses (54%), abdominal CT (50%), CT-guided interventions (43%), CT for urolithiasis (36%), high resolution CT of the chest (32%), and CT colonoscopy (14%). These rates show that nearly half of the respondents did not reduce scanning parameters according to the body parts being investigated. This may in part be explained by the fact that most radiologists in this survey are specialized according to body systems and not to the imaging modality. Although most respondents are dealing with more than one body system, relatively high frequency of chest (*n*=21), abdominal (*n*=18), and head and neck (*n*=12) radiologists might have influenced the application of low dose CT with respect to body parts.

Adjustment of scan parameters

The radiation dose delivered during CT scanning is related to tube current, voltage, scanning time, slice thickness, scanning volume, and pitch. Previous studies have suggested that it is feasible to reduce tube current without marked deterioration of image quality in CT of the head and neck, chest, abdomen, and pelvis (21-33). Our survey showed that reduced tube current is the most common modification reported by 93% followed by increased pitch (43%) and reduced peak kilovoltage (39%). Tube potential determines the X-ray beam energy, and radiation dose is proportional to the square of the tube voltage. In a recent study, it was shown that 80 kV was an acceptable setting for chest CT in adults weighing less than 75 kg, without substantial impairment in image quality (34). Using a16 detector-row CT scanner, Wintersperger et al. implemented an abdominal CT angiography protocol using 100 kVp and concluded that tube voltage reduction from 120 to 100 kVp allows for significant reduction of patient dose in abdominal CT angiography, without significant change in signal to noise and contrast to noise ratios and image quality (35). However, any decrease in tube current and voltage should be considered carefully, because they increase image noise, which may hamper diagnostic outcome of the information, particularly in low contrast areas, such as abdomen or brain. Pitch is defined as the ratio of table feed per 360^0 gantry rotation to the nominal x-ray beam width. An increase in the pitch decreases the duration of radiation exposure to the scan volume. However, effective milliampere second level is held constant regardless of pitch in scanners using effective milliampere second setting, defined as milliampere second divided by the pitch (36). No significant difference was demonstrated in image quality of scans obtained at a pitch of 1.5:1 compared to those obtained at a pitch of 0.75:1 saving 50% radiation dose in abdominal and pelvic imaging (37).

In a recent survey investigating the methods of dose reduction in pregnant patients suspected for pulmonary embolism, the most common modification was to decrease the scanning area along the *z*-axis, reported by 71% of respondents (9). In our survey only 14% of respondents indicated that they decrease the scanning length. Radiologists in our study group may be inclined to increase the area of coverage beyond the actual area of interest at the expense of higher effective radiation dose.

The availability of multislice CT scanners has resulted in a considerable increase in the number of CT procedures per patient and per scanner. A recent survey revealed that the mean effective dose to patients has increased from 7.4 mSv at single slice helical CT to 8.1 mSv at quad-slice CT system (38). Recent commercially available multislice CT scanners have automatic tube current modulation capability; that is the most important contribution of industry toward radiation dose optimization while simultaneously maintaining constant image quality regardless of patient attenuation characteristics. The two methods of this technique are z-axis modulation and angular (x-y axes) modulation. In 100 helical CT examinations in children, angular modulation was reported to decrease dose 10%-60% without loss of image quality (39). A recent investigation of 22 patients with kidney and ureteral stones in whom z-axis modulation was used showed a 43%-66% reduction in radiation dose at noise indexes of 14 and 20 without compromising stone depiction (40). In this survey, five (45%) of 11 respondents, who have multislice CT scanners, reported to use automatic tube current modulation technique.

Our survey has several limitations. First, because it is limited to radiologists who practice in an academic setting, our results are indicative of the current state of low dose CT strategies in academic environments. As academic radiologists are more likely to be aware of the low dose CT strategies, policies may differ significantly among radiologists in public hospitals or private practice. A second limitation of our study is that because only one response was allowed from each institution, it does not reflect the strategy of an entire department, because interindividual variations in the practice patterns could occur in the same institution. A third limitation is that our survey asked general questions with respect to dose reduction to a relatively heterogeneous group of academic radiologists working with different types of CT scanners. Specific questions directed to particular subspecialty radiologists regarding specific clinical indications would have more appropriately reflected the tendency of using low dose CT strategies. A fourth limitation is that, with regard to the frequency of low dose CT modifications, the choices given to respondents were not precise numbers, but rather arbitrary adverbs. Thus, excluding the respondents stating that they "always" optimize the scan parameters, other frequencies designated by "seldom", "sometimes", and "often" could have been overlapped. Similarly, in the question 6, we did not ask the absolute numbers for reducing the mA, kVp and increasing the pitch. Therefore, our rates for the application of low dose strategies might have been erroneously affected. For example, reducing mA from 400 to 300 may appear as low dose application, but indeed it is not at all.

In conclusion, our survey reveals that most radiologists are aware of the radiation dose the patient exposed during CT scan. However, the frequency of use of low dose CT strategies varies vastly, mostly due to the lack of well-established CT protocols designed for either specific indications or particular patients. In compliance with the rules of "as low as reasonably achievable", the radiologists should prepare practical CT dose optimization guidelines for routine practice depending on the body part being examined and indication for the study, or on the basis of patient's age and size.

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