Relationship between Radiation Dose and Image Quality in Lung CT scan In Hospital

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Abstract

The purpose of this study was to determine how changes in radiographic tube current affect patient dose and image quality in unenhanced chest CT examinations. Sixteen sets of CT images were obtained from 160 patients (112 Male, 48 Female) undergoing CT-chest scan (using CT-scan Model GE-64). For each patient, six images of the same region were obtained at settings between 240 and 300 mAs. CT data were used to reconstruct topographic sections with a field of view limited to the normal contra lateral lung. Images were printed using lung and mediastinal image display settings. Image quality was determined by asking radiologists to assess the perceived level of mottle in CT images. The same set of images were also evaluated by MATLAB(8.1) on the bases of standard deviation , Patient effective doses and risk factor were computed for chest CT examinations performed at each milliampere-second setting Differences in CT image quality for radiographic techniques between 300 and 400 mAs were deemed to be insufficient to justify any additional patient exposure. However, the use of 300 mAs results in an inferior image quality that would justify increased patient exposure.

This image quality is confirmed by both methods , radiologist assessment and MATLAB assessment .Therefore, radiographic techniques for unenhanced chest CT examinations can be reduced from 400 to 300 mAs without compromising image quality.

Keywords: This work was carried out in ABOSALEM Trauma Hospital

Introduction:-

The introduction of CT into clinical practice in 1972 has been followed by a dramatic increase in the number of CT examinations performed [1,2] More than 27 million CT examinations were performed in the United States in 1997, an increase of 10% per year [3]. With the advent of improved CT technology such as multislice detectors, the use of CT in diagnostic radiology will continue to increase for the foreseeable future. Radiation doses delivered to the patients undergoing CT examinations are relatively high in comparison with doses associated with other types of diagnostic radiologic procedures. In 1989, CT represented only 4% of the radiologic examinations performed in the United Kingdom, yet accounted for more than 40% of the collective medical radiation dose to the population [4].

Radiation doses in CT are well below the threshold doses for the induction of deterministic effects such as erythema and epilation [5].

Patient risks from chest CT examinations are therefore restricted to the stochastic processes of carcinogenesis and the induction of genetic effects. The radiation received by a patient undergoing any type of diagnostic radiologic examination is best quantified by the effective dose [6]. Typical values for the effective dose for patients undergoing chest CT examinations are about 5 mSv [7]. Patient doses may be lower if high-resolution CT is performed using thin sections [8], or higher if both unenhanced and contrast-enhanced images are generated.

For any CT examination performed at a fixed radiographic tube potential, the patient dose is directly proportional to the value for milliampere-seconds selected by the operator. The choice of milliampere-seconds also determines the amount of quantum mottle in the resultant image [9, 10]. High values for milliampere-seconds could result in the patient being overexposed, whereas low values could result in poor image quality, with a risk of the radiologist missing clinically important findings. According to the recommendations of the International Commission on Radiological Protection, patient doses in CT should always be kept as low as reasonably achievable [11].

In this study sixteen sets of CT images were obtained from 160 patients undergoing CT- chest scan at ABOSALEM Trauma Hospital. For each patient, six images of the same region were obtained at settings between 280 and 300 mAs. CT data were used to reconstruct tomographic sections with a field of view limited to the normal contralateral lung. Images were printed using lung and mediastinal image display settings. Image quality was determined by asking radiologists to assess the perceived level of mottle in CT images. Three chest radiologists ranked the relative image quality of sixteen images. The same images were also tested for image quality by using MATLAB software version(8.1) ,Patient effective doses and risk factor were computed for chest CT examinations performed at each milliampere-second setting. Radiologists indicated whether any perceived improvement of image quality at the higher radiation exposures was worth the additional radiation dose.

Experimental Procedures

CT scans were all obtained at 120 kVp on a CT- scanner (General Electric -64). Initial scanning was performed using 300 mA and a scan time of 1 sec, corresponding to a radiographic technique of 300 mAs. Scans were obtained using 5-mm collimation and a pitch of 1.5:1 to generate a set of four to five helical images using a 5-mm reconstruction interval and a “detail” reconstruction algorithm. The first such set was obtained at 300 mA, which is the standard for chest CT examinations at ABOSALEM Trauma Hospital. Subsequent sets were obtained at decreasing levels of 220, 160, 120 mA in order to decrease the cumulative radiation dose in a repeatedly imaged region. Each set of images was assessed immediately after reconstruction by the radiologist .

These images were printed to a laser camera using a 3 × 4 format, in pairs consisting of lung (window width, 1500 H; level, -500 H) and mediastinal (window width, 450 H; level, 40 H) settings, one group with and another without annotation. Figure 1.1,1.2 shows a series of representative images obtained at 280, and 300 mAs

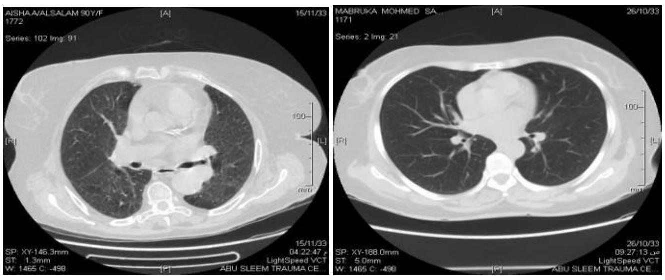


Fig. 1.1.Representative images of two set chest images of female patient printed using lung and mediastinum window at 280 mAs

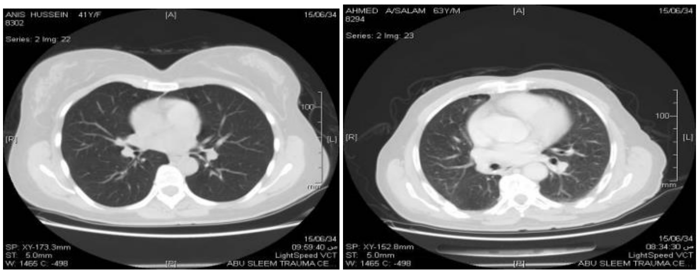


Fig. 1.2.Representative images of two set chest images of male patient printed using lung and mediastinum window at 300 mAs

Evaluation of image quality versus mAs

Sixteen patient images were randomly selected from 160 cases. For each patient examination, four images lacking any annotation were generated on sheets of 14 × 17 film. Each film was placed in random order in an envelope, resulting in 16 envelopes containing two pairs of images. Three interpreters, all board-certified radiologists who routinely review chest CT images, were used in this study. Each observer was asked to order the two pairs of images in each envelope according to image quality, from best to worst, which was completed in a single sitting. For each observer, the average rank was computed for 16 images generated at each technique factor.

In this manner, average ranks for each observer were obtained at each technique factor. Observers were also asked to explicitly identify any images that were deemed to be of less than diagnostic quality.

The expected rank of CT images obtained at 300 mAs would be 4, whereas the rank of images obtained at 280 mAs would be 3

MATLAB Software

Matlab is a data analysis and visualization tool which has been designed with powerful support for matrices and matrix operations. And its own powerful programming language. One of the reason that MatLab has become such an important tool is through the use of sets of MatLab programs designed to support a particular task. These sets of programs are called toolboxes, and the particular toolbox of interest to us is the image processing toolbox which we have been used to assess the image quality in this work, the toolbox used for this purposes is standard deviation (sd1). All the images has been entered as input data and standard deviation for each image has been calculated. Images with high sd1 will have best image contrast.

Patient Doses and Risks

For a given patient undergoing a chest CT examination, the effective dose depends on the choice of technique factors, including the peak kilovoltage, milliampere-seconds, section thickness, and number of sections. The total mass of the patient that is directly irradiated may be modeled as a cylinder of water on the basis of the dimensions and mean Hounsfield unit values obtained from representative axial CT images. This procedure permits the computation of the mean patient dose and total energy imparted for a given chest CT examination. At a fixed radiographic tube potential, the patient effective dose is directly proportional to the selected tube current, the section thickness, and the total number of sections obtained. In our study ,an adult patient having 48 sections, each of which is 5 mm thick, generated at 120 kVp and 300 mAs, will receive an effective dose of about 3.0 mSv [53]. The predominant risk to patients undergoing chest CT is the induction of cancer. Although some uncertainty exists about the radiation risks at the exposure levels normally encountered in diagnostic radiology [54], the best estimate currently in use for the general population is a 5% risk per sievert for cancer mortality [55]. An effective dose of 3 mSv for a chest CT scan thus corresponds to a nominal cancer fatality risk of approximately 1.5 per 10,000 patients. Table 1.1 summarizes the patient effective doses for the range of technique factors used in this study and the corresponding radiation risk factors.

Table1. 1 Patient input data for GE-scanner-64 at ABSALEM Trauma Hospital And total effective dose for each patient and the corresponding risk factor

slice thickness	sex	Age	Organ	No. of slices	mAs	Risk factor per 10000	Dose (mGy-mm)	Number
5	M	33	CHEST	48	300	1.96	943.71	1
5	M	23	CHEST	48	300	1.66	801.11	2

5	F	27	CHEST	48	300	1.27	610.8	3
5	F	57	CHEST	48	300	1.80	865.2	4
5	F	43	CHEST	48	300	1.56	749.91	5
5	F	26	CHEST	48	300	1.57	785.15	6
5	F	75	CHEST	48	300	0.93	466.12	7
5	M	19	CHEST	48	300	0.90	451.97	8
5	M	50	CHEST	48	300	1.64	820.38	9
5	M	20	CHEST	48	300	1.88	943.71	10
5	M	33	CHEST	48	300	1.88	943.71	11
5	M	20	CHEST	48	300	1.81	908.47	12
5	M	30	CHEST	48	300	1.99	996.57	13
5	M	23	CHEST	48	300	1.60	801..11	14
5	F	43	CHEST	48	300	1.49	749.91	15
5	M	65	CHEST	48	300	1.81	908.47	16

Results and Discussion

The overall mean scores for all image quality details for different lung CT scan at initial 300 mAs and slice thickness of 5 mm were shown in Fig 1.3 The overall image quality scores for all examinations was evaluated by three different radiologist.

Radiologists participating in this study varied widely in their ability to differentiate the image quality of CT studies performed at different technique factors. Observer 1, for example, was almost perfect in ranking the images obtained at the different tube current values, whereas observers 2 and 3 clearly could not differentiate between images generated at 280 mAs and those generated at 300 mAs. All observers, however, had no difficulty in identifying the images obtained at 40 mAs as being the worst.

Fig 1.3 shows the average score for the three observers plotted against the effective dose and the values of standard deviation calculated by MATLAB for each image, its clear that, image number 1 as shown in Fig 1-A has been given high score by the three radiologist 4 out of 4.i.e the over all score 12 as shown in Fig 1.3 which was corresponding to standard deviation (80.24) and effective dose 3.18 mSv.

Image number 2 as shown in Fig 1-A has been given less score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in Fig 1.3 which was corresponding to standard deviation (86.90) and effective dose 3.78 mSv.

Image number 3 and 4 have been given lowest score by the three radiologist, and this score has been confirmed by MATLAB analysis as lower value of Sd (79.69).

The variation in image quality in there four images might be attributed to the change in tube current during scanning . this change in operation current will effect dramatically the signal to noise ratio which has major effect on contrast and image quality

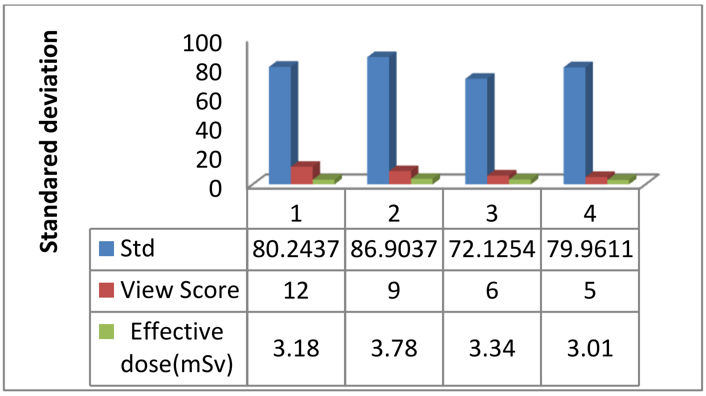


Fig 1.3 The correlation between the effective dose and image contrast for four CT lung images evaluated by three radiologists as score and by MATLAB as standard deviation

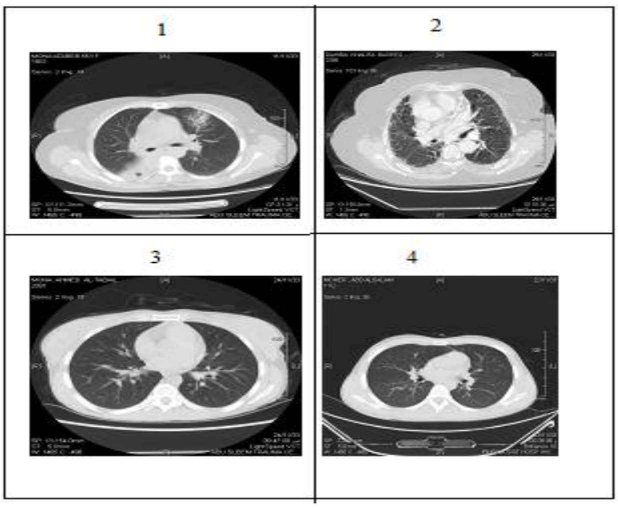


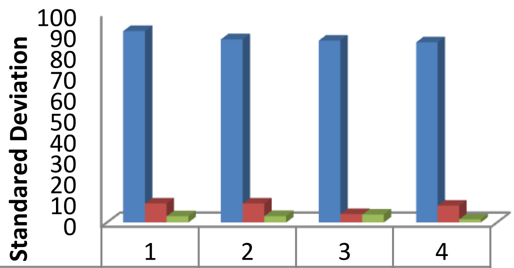
Fig 1-A Lung CT scan at different tube current

Fig 1.4. shows the average score for the three observers plotted against the effective dose and the values of standard deviation calculated by MATLAB for each image, its clear that, image number 1 as shown in Fig 3-B has been given fair score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in 1.4 which was corresponding to standard deviation (91.21) and effective dose 2.97 mSv.

Image number 2 as shown in Fig 1.B has been given less score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in Fig 1.1 which was corresponding to standard deviation (87.27) and effective dose 3.05 mSv. Image number 3 and 4 have been given lowest score by the three radiologist, and this score has been confirmed by MATLAB analysis as lower value of Sd (85.84).

The variation in image quality in there four images might be attributed to the change in tube current during scanning . this change in operation current will effect dramatically the signal to noise ratio which has major effect on contrast and image quality.

Its clear that image number in Fig 1-B has higher sd (91.21) and less effective dose (2.97 mSv) compared to image number 1 in Fig 3.A which has high score and high effective dose (3.18 mSv), this minor reduction in image quality in Fig 1.4-A and Fig 1-B was perceived, but the radiologists in this study did not generally consider that the difference in image quality would justify any increase in patient radiation exposure.



	1	2	3	4
Std	91.214	87.2758	86.673	85.8493
Viewer score	9	9	4	8
Effective Dose(mSv)	2.97	3.05	3.78	1.5

Fig 1.4 The correlation between the effective dose and image contrast for four CT lung images evaluated by three radiologists as score and by MATLAB as standard deviation

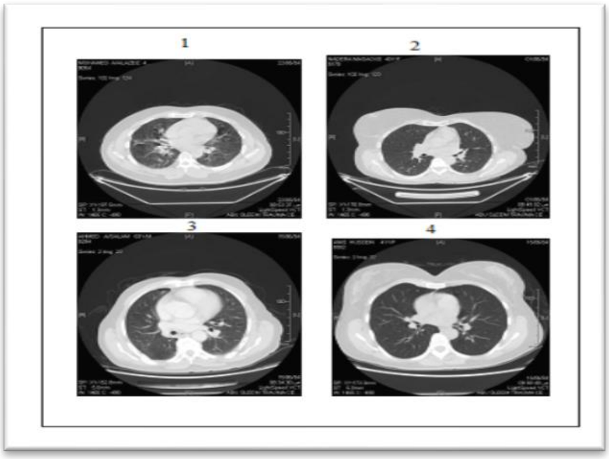
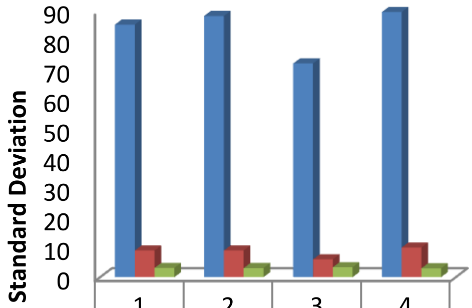


Fig 1-B Lung CT scan at different tube current

Fig 1.4 shows the average score for the three observers plotted against the effective dose and the values of standard deviation calculated by MATLAB for each image, its clear that, image number 1 as shown in Fig 1-C has been given fair score by the three radiologist 3 out of 4.i.e the overall score 9 as shown in Fig 1.4 which was corresponding to standard deviation (91.21) and effective dose 2.97 mSv

Image number 2 as shown in Fig1.B has been given less score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in Fig 3.1 which was corresponding to standard deviation (87.27) and effective dose 3.05 mSv.

Image number 3 and 4 have been given lowest score by the three radiologist, and this score has been confirmed by MATLAB analysis as lower value of Sd (85.84).



	1	2	3	4
Std	85.2263	88.1609	72.1254	89.5078
Viewer Score	9	9	6	10
Effective dose (mSv)	3.12	3.05	3.34	2.97

Fig 1.4 The correlation between the effective dose and image contrast for four CT lung images evaluated by three radiologists as score and by MATLAB as standard deviation

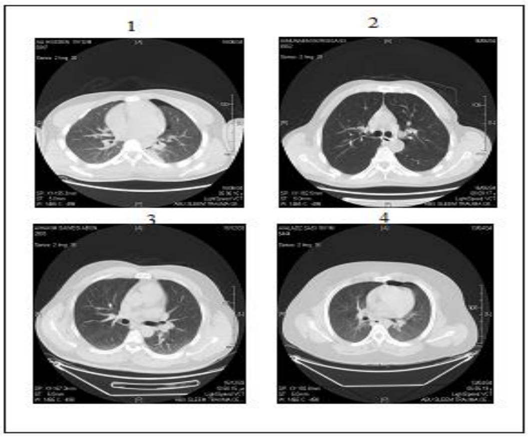


Fig 1-C Lung CT scan at different tube current

Fig 1.4 shows the average score for the three observers plotted against the effective dose and the values of standard deviation calculated by MATLAB for each image, its clear that, image number 1 as shown in Fig 1-B has been given fair score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in Fig 6.4 which was corresponding to standard deviation (91.21) and effective dose 2.97 mSv.

Image number 2 as shown in Fig 3.D has been given less score by the three radiologist 3 out of 4.i.e the over all score 9 as shown in Fig 3 which was corresponding to standard deviation (87.27) and effective dose 3.05 mSv.

Image number 3 and 4 have been given lowest score by the three radiologist, and this score has been confirmed by MATLAB analysis as lower value of Sd (85.84)

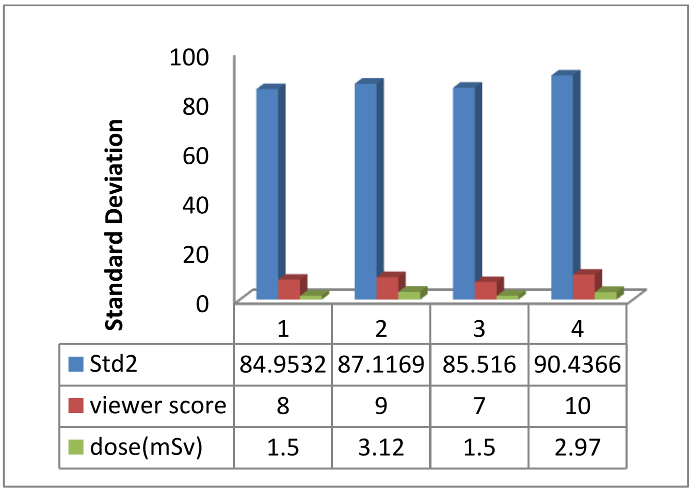


Fig 1.4 The correlation between the effective dose and image contrast for four CT lung images evaluated by three radiologists as score and by MATLAB as standard deviation

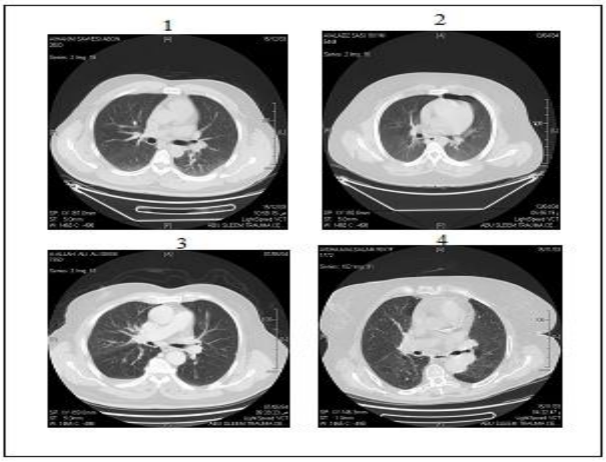


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Fig 1-D Lung CT scan at different tube current

DISCUSION:-

CT images acquired for any given patient and reconstructed using the same filter and field of view will have identical values of spatial resolution. At a constant radiographic tube potential, image contrast in chest CT images depends only on the choice of the window and level print settings, which were kept constant throughout the study. Inspections of all 16 series of images indicated that no gross artifacts were caused by implants or patient motion. As a result, it is reasonable to conclude that the only image quality variable being evaluated in this study was the amount of mottle visible in the image. In CT, the amount of image mottle depends on the total number of photons used to produce the image, which is a function of the selected value for milliampere-seconds. Observers were therefore explicitly informed that the image quality issue being considered was image mottle, to ensure that they did not rank images in terms of contrast, spatial resolution, or artifacts.

Image quality was ranked on a relative scale, an approach that has been shown to be an efficient method for identifying small differences in image quality [17]. No attempt was made to generate an absolute assessment of image quality except for a general assessment as to whether the images were of diagnostic quality. Evaluating CT image quality with more objective criteria can assess the ability to see second and third order bronchi and vessels on lung windows and the differentiation of soft-tissue structures (blood vessels and lymph nodes) within fat on mediastinal windows [18].

This approach was not used in this study because the approach does not explicitly refer to image mottle, and because this type of image quality metric often shows little correlation with patient radiation dose [19]. The use of a relative scale is further justified by the fact that the images being ranked were from the same patient. In addition, our study did not contain any pathologic abnormalities, and no attempt was made to assess the delineation of pathologic abnormalities. Previous studies have clearly suggested that the radiographic exposure level as expressed by the tube current can be reduced when performing chest CT examinations [20]. The findings of our study are in good agreement with those of Mayo et al. [21], who found that reducing the tube current from 400 to 140 mAs did not significantly change subjective image quality or the detection of mediastinal or lung abnormalities. However, performance is generally task-dependent, and this study evaluated only the performance for unenhanced chest CT examinations. For contrast-enhanced images, further study would be required before any reduction in the level of X-ray exposure is considered.

Further reductions in tube current may be possible for cancer screening and high-resolution CT. In general, screening tasks use only lung window settings, where the perception of image mottle would be markedly lower than on the corresponding mediastinal window settings. Two recent studies indicate that it may be possible to use tube currents and scanning times that result in values between 20 mAs and 40 mAs when performing screening studies [22,23].

However, other experimental and clinical studies for the detection of pulmonary nodules have also shown that low-dose CT performed using a tube current of 50 or 25 mA could significantly impair the detection of nodules 5.5 mm or smaller [24].

Image quality per se is not the critical issue in diagnostic radiology, for which correct diagnosis is the ultimate goal. Additional radiation to improve image quality will not necessarily add to the diagnostic quality of the examination. Image quality may be perceptibly worse, particularly with increased noise, but if normal and abnormal structures can be easily identified, then the image is still of diagnostic quality. As an example, a recent study showed that although reducing the CT technique from 250 to 50 mAs resulted in noisy images, no significant difference was seen in the detection of lung and mediastinal abnormalities [25].

Also, the minimum tube current required for screening may be different for different locations in the lung [26]. In this study, the radiographic tube potential was kept constant, because a constant voltage is currently the normal mode of operating clinical CT scanners in North America. Changing the CT radiographic tube potential also needs to be considered in defining CT imaging protocols, which will affect both image contrast and noise [27]. The radiographic tube potential would ideally be altered to ensure that the contrast-to-noise ratio is adequate for a given imaging task. Changing the radiographic tube potential, however, will also have a significant effect on the patient dose. If the patient radiation dose is not a major factor, the optimum tube voltage should be the one that produces good quality images to avoid missing important diagnostic information. For high-dose procedures, or when exposing radiosensitive patients such as infants and pregnant women, a more careful evaluation of image quality and patient dose should be undertaken.The risk estimates in Table 6.1 were computed on the basis of the accepted nominal risk coefficients used by the International Commission on Radiological Protection for radiation protection purposes [15]. Considerable uncertainty exists about the radiation risks associated with low-dose CT. Most published data for radiation-induced carcinogenesis have been obtained at relatively high organ doses, typically greater than 0.25 Gy, whereas individual organ doses in chest CT are much lower (<0.02 Gy). Current national and international bodies assume that low doses of radiation are associated with a radiation risk, and that the use of radiation must take this into account. As a result, any use of radiation in patients needs to be formally justified by ensuring that the individual patient will be expected to benefit from the information gathered. In addition, any radiation exposure should be minimized to ensure that the patient is not subjected to unnecessary exposure.

The most important aspect of this study was the attempt to explicitly address the issue of whether any perceived improvement of image quality at a higher radiation level is deemed to be worth the additional radiation dose received by the patient. Radiologists and other imaging professionals who are responsible for developing scanning protocols need to address the trade-off between patient dose and image quality for each diagnostic imaging study. This balancing of dose and image quality should be performed explicitly to ensure that patient doses are kept as low as reasonably achievable. Selection of technique factors in this manner must take into account the scanned population, because subgroups such as infants and pregnant women may be more radiosensitive than others. In addition, the optimum technique factor will depend on the specific task at hand. For example, low-dose CT is being promoted for general screening applications, whereas high-dose CT may be appropriate for the detection of some subtle diseases. At our institution, we perform all chest CT at a fixed radiographic tube potential (120 kVp) and a fixed radiographic tube output (280 mA), together with a constant scan time (1 sec) and a section thickness of 7 mm. In practice, minor changes are made to the actual tube current because of the commercial system used (SmartScan; General Electric), which automatically adjusts the tube current depending on the dimensions of the body part being scanned.

Our study results indicate that reducing the radiographic tube current to no more than 140 mA would be justified for performing adult chest CT examinations. The section thickness for routine chest CT examinations is 7 mm, whereas the section thickness in this study was 5 mm, which would imply that greater reductions in technique factors may be possible. We are therefore planning to reduce the chest CT technique factors used clinically in an incremental manner while the resulting image quality for all types of studies is monitored. In this manner, we will empirically determine whether the results obtained in this study are applicable for the whole range of CT chest studies, including contrast-enhanced and unenhanced studies. As a result, we expect to implement CT protocols that explicitly attempt to ensure that patient doses are kept as low as reasonably achievable without compromising diagnostic performance.

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