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Study of Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with fixed another parameter

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Abstract

High-quality and detailed computed tomography (CT) images are essential for accurate diagnosis. Factors such as image noise and slice thickness affect image quality. This study aimed to determine the optimal slice thickness that minimizes image noise while maintaining adequate diagnostic information using multi-slice CT (MSCT). To investigate the effect of slice thickness on noise and contrast in images, four patients who underwent abdominal CT scans were consecutively studied. They were scanned at two levels of slice thickness: 2 mm and 5 mm, and 3 mm and 5 mm, respectively other parameter are the same.

Then, quantitative analysis was performed. The study showed that thin slice thickness led to: Reduced image noise Increased contrast Improved detection Therefore, a balance should be considered between changing slice thickness and diagnostic content and image noise., slice thickness of 2 mm was identified as an optimal choice to minimize image noise and achieve better and more accurate detection using a single-source head CT protocol. The study also revealed that image noise tends to increase with increasing slice thickness.

الملخص

تعد صور الأشعة المقطعية المحوسبة عالية الجودة والمفصلة أمرًا ضروريًا للتشخيص الدقيق, وتتأثر جودة الصورة بعوامل مثل ضوضاء الصورة وسماكة الشريحة .هدفت هذه الدراسة إلى تحديد سماكة الشريحة المثالية التي تقلل من ضوضاء الصورة مع الحفاظ على معلومات تشخيصية كافية باستخدام التصوير المقطعي المحوسب متعدد الشرائح.(MSCT) للتحقق من تأثير سماكة الشريحة على الضوضاء والتباين في الصور، تم إجراء مسح على أربعة مرضى خضعوا لتصوير مقطعي محوسب للبطن بشكل متتابع .وتم مسحهم على مستويين من سماكة الشريحة 2 مم و5 مم، و3 مم و5 مم على التوالي .أظهرت الدراسة أن سماكة الشريحة الرقيقة أدت إلى:تقليل ضوضاء الصورة وزيادة التباين لذلك يجب مراعاة توازن بين تغيير سماكة الشريحة والمحتوى التشخيصي وضوضاء الصورة، تم تحديد سماكة شريحة 2 مم كخيار مثالي لتقليل ضوضاء الصورة وتحقيق اكتشاف أفضل وأكثر دقة ,كما كشفت الدراسة أن ضوضاء الصورة تميل إلى الزيادة مع زيادة سماكة الشريحة.

Introduction

Concerns have grown regarding the high radiation doses patients are exposed to during computed tomography (CT) scans. While these scans provide detailed images of internal organs, the radiation dose received by a patient, which can reach approximately 1-2 millisieverts for head scans and 4-6 millisieverts for full body scans, is considered high compared to many other types of radiological examinations.

The radiation doses resulting from computed tomography (CT) scans are significantly higher compared to the natural background radiation that humans are exposed to daily, which is estimated to be about 3 millisieverts per year. These doses also exceed the permissible limits for radiation exposure for the general public, which is estimated at 1 millisievert per year. When compared to the highest permissible level of occupational radiation exposure, which is approximately 20 millisieverts per year.[1]

With the increasing use of multi-slice technology in computed tomography (CT) scans, it has become essential to study the complex relationship between radiation dose and image quality. On one hand, this technology contributes to obtaining more detailed and accurate images, but on the other hand, it leads to an increase in the radiation dose received by the patient. This study will investigate the impact of adjusting kVp and mAs values in X-rays on this relationship, with the aim of determining the optimal settings that achieve the best balance between quality and dose.

The goal of this project is to study the main CT operating factors for dose reduction to patient without affecting image quality. The introduction of computed Tomography (CT) into clinical practice in 1972 has been followed by a dramatic increase in the number of Computed Tomography examinations performed. More than 27 million CT examinations were performed in the United States in 1997, an increase of 10% per year [2].

With the advent of improved Computed Tomography technology such as multislice detectors, the use of CT in diagnostic radiology will continue to increase for the foreseeable future. Radiation doses delivered to patients undergoing Computed Tomography examinations are relatively high in comparison with doses associated with other types of diagnostic radiologic procedures.

In 1989, although computed tomography (CT) scans accounted for only 4% of all radiological examinations in the United Kingdom, they were responsible for over 40% of the total medical radiation dose received by the population. [3]

Radiation doses in Computed Tomography are well below the threshold doses for the induction of deterministic effects such as erythema and epilation [4]

Patient risks from chest Computed Tomography 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 [5]. Typical values for the effective dose for patients undergoing chest Computed Tomography examinations are about 5 mSv [6].

Patient doses may be lower if high-resolution Computed Tomography is performed using thin sections [7], or higher if both unenhanced and contrast-enhanced images are generated.

For any Computed Tomography 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 [8-9].

Increasing the milliampere-seconds (mAs) value raises the risk of radiation exposure to the patient, while lower values result in poor image quality, which could lead doctors to miss important medical findings.

According to the recommendations of the International Commission on Radiological Protection (ICRP), patient doses in Computed Tomography should always be kept as low as reasonably achievable [10].

In this study, the researcher took the advantage of the Computed Tomography units in both cities and the generated images for Chest patients during normal CT scanning procedures to investigate.

The CT image procedures have a well-defined imaging task of identifying the main various chest normal marker relative to an identifiable lesion. This well-defined task permits the reduction of radiographic tube current value i.e. mAs, at a constant scan time, slice thickness, slice number, kVp and pitch number.

Projection data acquired in this manner can thereby be used to reconstruct the normal chest to permit the systematic investigation of the effect of the tube current setting on patient dose and image quality.

Literature review

Effect of slice thickness on image noise and diagnostic content of single source – dual energy computed tomography Marwan alshipli. And norlaili A.Kabir. 2017, School of physics, University Sains Malaysia,11800, Pulau Pinang. Malaysia. The image analyses show that image noise decrease with the increase of slice thickness. However, comparative study was conducted at the Rosz Halat emergency department in Erbil, Kurdistan region of Iraq, from 19 Feb 2022 to12 May 2022.

A study was conducted on 15 patients to evaluate the impact of slice thickness on image quality in single-source computed tomography (SSCT) head scans. Image analysis software was used to assess the images and improve diagnostic accuracy. In this study, the changes in noise associated with slice thickness were investigated. findings provide a valuable reference for maintaining high image quality standards in CT examinations. The analysis, conducted using Linux, showed that as slice thickness decreases, image noise is reduced. Thus, a significant difference was observed in the noise of DICOM images obtained at thicknesses above 3.75 mm. As diagnostic value increases with decreasing slice thickness, 1.25 mm was chosen as the optimal slice thickness to balance noise reduction and maintain the required image quality in single-source multi-slice computed tomography.

Technical Parameters: Display and Exposure Parameters with an Influence on Image Quality and Dose.

Nominal slice thickness

Slice thickness in computed tomography (CT) refers to the thickness of the tissue layer being imaged. As slice thickness increases, the level of detail that can be seen in the image decreases, but noise also decreases. Conversely, as slice thickness decreases, the level of detail increases, but noise also increases. The radiologist selects the appropriate slice thickness based on the type of examination being performed. [11,12]

Volume of investigation

The scan volume in computed tomography refers to the entire body area being imaged. As this area increases, the amount of radiation exposure to the patient also increases, unless certain technical precautions are taken. The technician determines the appropriate scan volume based on the area to be examined.

Field of view

The size of the area we focus on in a medical image can be adjusted. The smaller the area, the clearer the details in the specific region of interest. However, the size must be appropriate to include all the parts we want to examine. This choice helps the doctor make a more accurate diagnosis.

Aim of the Study

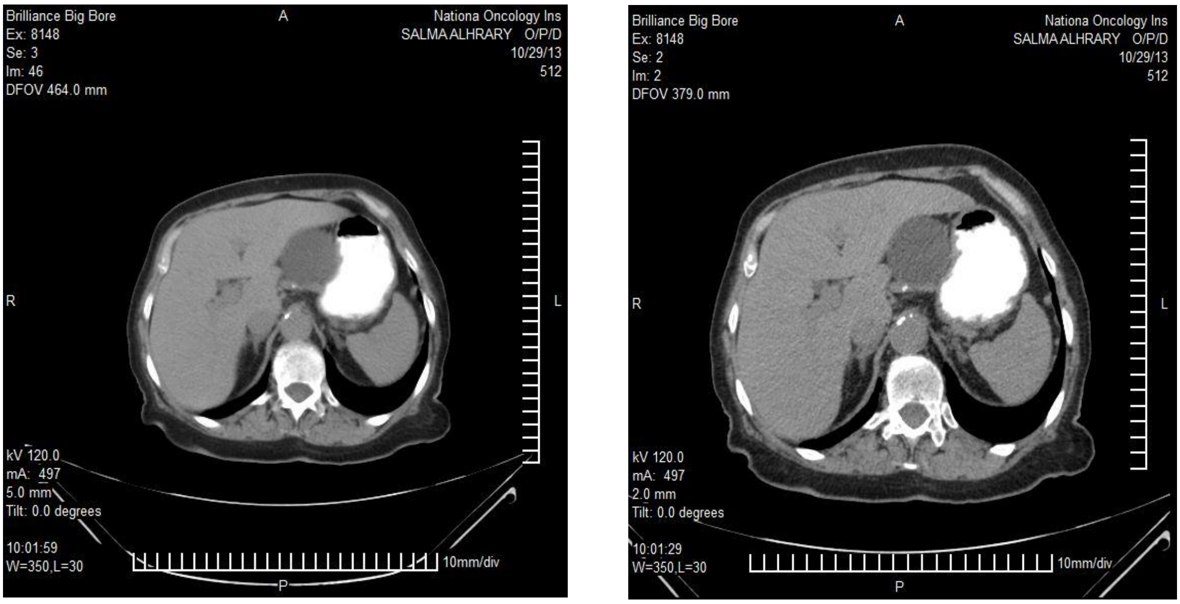
1. The main aim of the study is to evaluate the CT-Abdomen images quality with lowering overall patient radiation doses.by change slice thickness.
2. To familiarize the researcher with the mains of CT imaging concepts for lowering the patient radiation dose.
3. The purpose of this study was to determine how the slice thickness effect image quality specifically for abdomen CT examination.

Materials and methods

Practical Images at the African Oncology Institute-Sabratha The data collected from 5 patients listed in one group underwent CT examination in African Oncology institute-Sabratha, /Radiology Department during which the examination using various CT- slice thickness, tube current mAs and the kVp, was constant.

1) Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with fixed another parameter.

Patient No.	**Age**	**Part**	**kVp**	**mAs**	**$CTDI_{VOL}$**	**Scan length**	**Slice Thickness**	**Field of view**
8148 A	70y	Abdomen	120	265mAs	14 mGy	455.0	5 mm	pitch 0.9
8148 B	70y	Abdomen	120	265mAs	14 mGy	455.0	2 mm	pitch 0.9



A
Thickness 5.0 mm

B
Thickness 2.0 mm

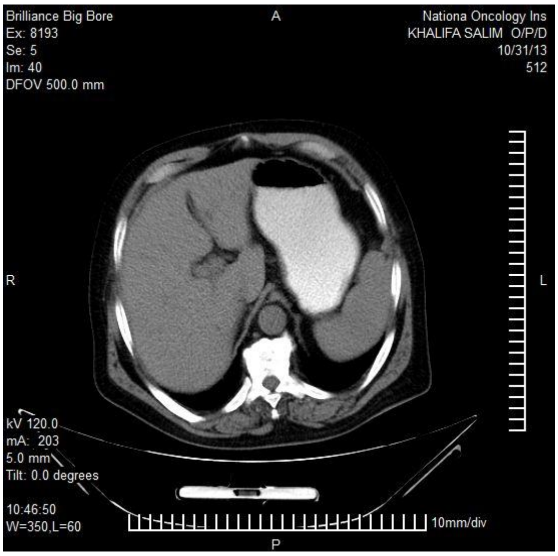
Figure 1 (A-B)

Patient no. (8148), 70y age, (patient have cystic lesion at body of pancreas 5.3 Cm), (W=350, L=30) (A)-slice thickness5.0 mm, but (B)-slice thickness 2.0mm, other parameter is the same kVp 120, mAs 265 mAs, CTDI 14mGy, thickness slice (5mm, 2mm) scan length 455.0, pitch 0.9.

It has to be noted that when the slice thickness is decreased to improve detail, the noise level will increase because of the smaller Voxels.

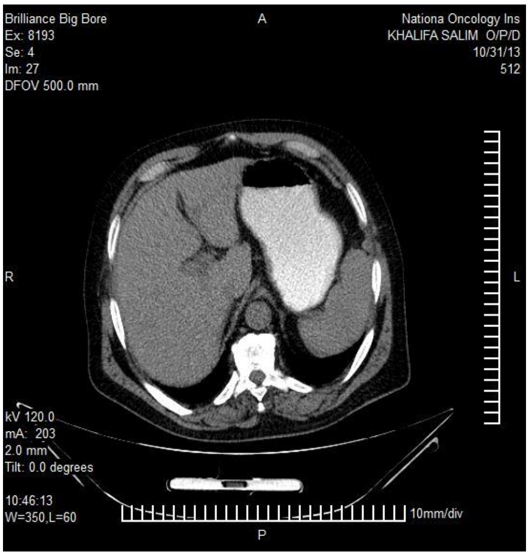
(2) Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with fixed another parameter.

Patient No.	Age	Part	kVp	mAs	$CTDI_{VOL}$	DLP	Scan length	Slice Thickness	Field of view
8193A	70Y	Abdomen	120	203mAs	22.8mGy	243.63mGy*cm	88.5mm	5mm	197.0mm
8193B	70y	Abdomen	120	203mAs	22.8mGy	244.76mGy*cm	89.0mm	2mm	175.0mm



A

Thickness 5.0 mm



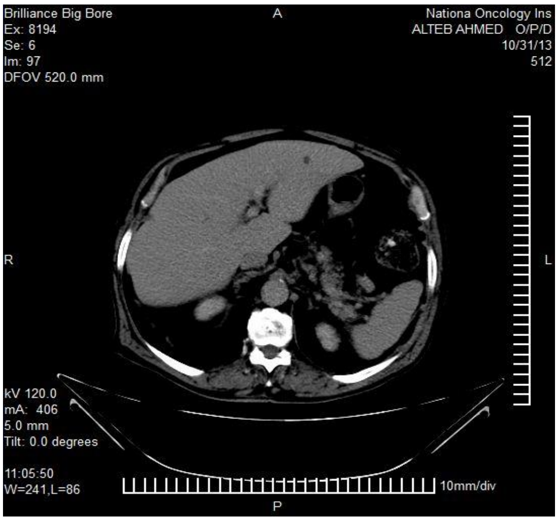
B

Thickness 2.0 mm

Figure 2 (A-B) Patient No (8193) 70y. age without i.e. contrast, oral contrast only, (W=350, L=60) (A)-slice thickness5.0 mm, but (B)-slice thickness 2.0mm, another parameter is the same.

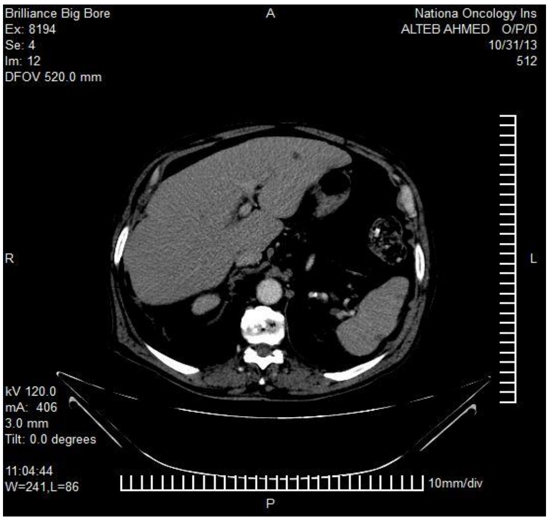
3- Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with fixed another parameter.

Patient No.	Age	Part	kVp	mAs	Slice Thickness	Field of view
8194A	80y	Abdomen	120	406mAs	5mm	520.0mm
8194B	80y	Abdomen	120	406mAs	3mm	520.0mm



A

Thickness 5.0 mm



B

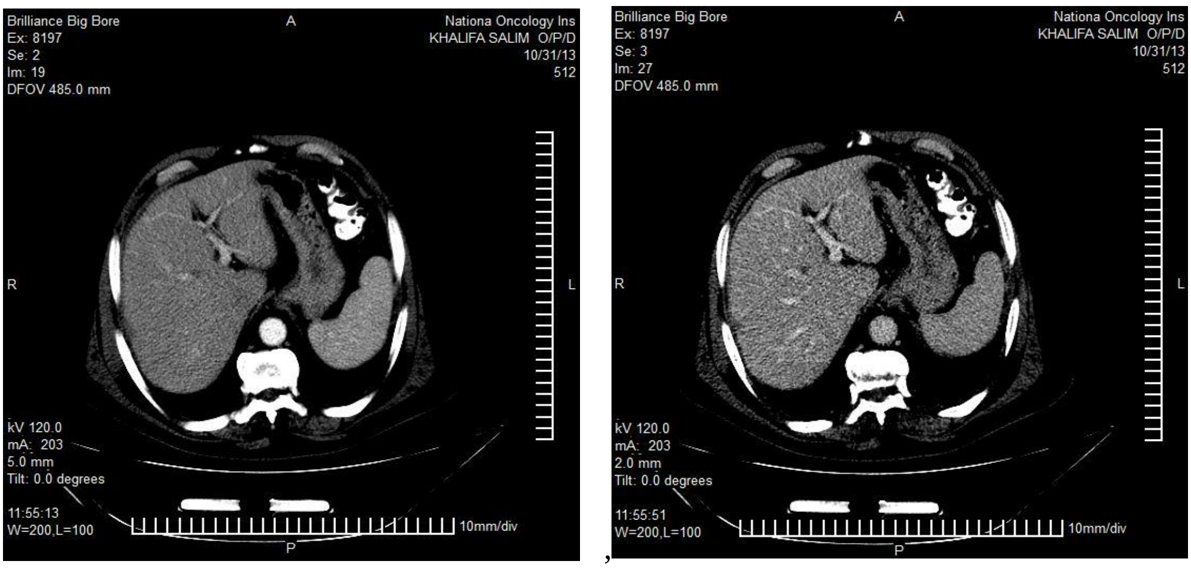
Thickness 3.0 mm

Figure 3(A-B): patient No (8194), 80y diagnosis (non-Hodgkin, lym phoma) - post 6 cycle chemotherapy, (W=241, L=86) (A)-slice thickness 5mm, but (B)-slice thickness 3mm, another parameter is the same.

Effect of slice thickness on image quality variables.

Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with(4) fixed another parameter

Patient No.	Age	Part	kVp	mAs	W	L	Slice Thickness	Field of view
8197A	70y	Abdomen	120	203mAs	200	100	5mm	485.0mm
8197B	70y	Abdomen	120	203mAs	200	100	2mm	485.0mm



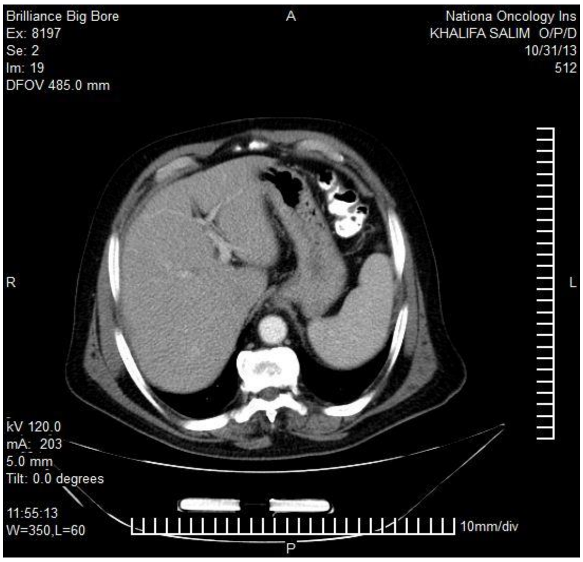
A **B**

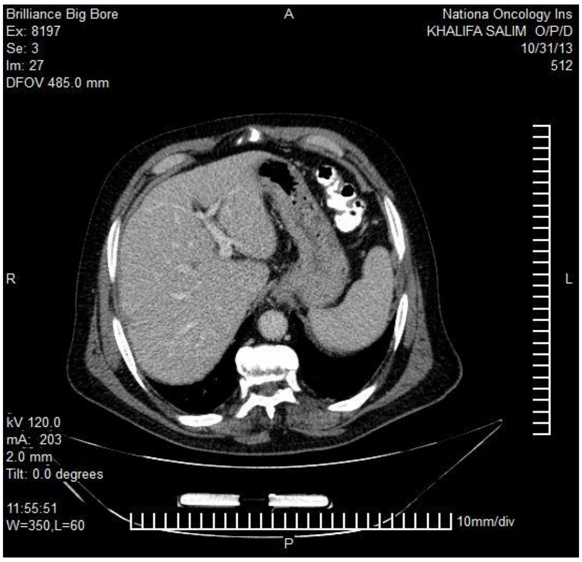
Thickness 5.0 mm **Thickness 2.0 mm**

Figure 4 (A-B): patient No. (8197). Age 70y, (Liver window W=200, L100) Abdomen window (A)-slice thickness5.0 mm, but (B)-slice thickness 2.0mm, another parameter is the same.

(5) -Relationship between the slice thickness vs. image Quality in Abdomen CT Examinations with fixed another parameter

Patient No.	Age	Part	kVp	mAs	W	L	Scan length	Slice Thickness	Field of view
8197A	70y	Abdomen	120	203mAs	350	60	100	5mm	485.0mm
8197B	70y	Abdomen	120	203mAs	350	60	100	2mm	485.0mm





A — Thickness 5.0 mm

B — Thickness 2.0 mm

Figure 5(A-B) Patient No (8197) 70y ages (W=350, L=60), Abdomen window (A)-slice thickness 5.0 mm, but (B)-slice thickness 2.0mm, another parameter is the same.

The image quality was determined by two radiologists to assess the quality.

For each patient examination, the images lacking any annotation were generated on CD's. Each disk was handed out and placed in random order and were given to each radiologist for evaluation of images. These two interpreters, all were board-certified radiologists who routinely review abdomen CT images, were used in this study and ranking the relative image quality from one plus sign to acceptable (+), two plus signs to good (++) and three plus signs to very good (+++) from worst to best for each patient.

(each patient has 3sets in different mAs).

A special format has been prepared to evaluate the images taken under different settings of imaging procedures, as shown in Table (5.8).

Table 6- Presents the CT image quality evaluation by radiologists.

Types of the Image	Slicethickness 2mm	Slicethickness 5 mm
Topogram	+ + +	+ ++
abdomen soft tissue	+ + +	++
Liver	+ + +	+ +
- Muscle	+ + +	++

At the same time the slice thickness for each set of patients that means the average of (2.0 mm-5.0 mm) figures with the same mAs to study its effect on the image quality effects.

Also, the image processing by using matlab-7 give good practical approach which will enhance the image quality.to measurement The standard deviation(S) of residual per each segment is the upper bound of the noise level in that segment.

Conclusion

The image quality was determined by two radiologists from sabratha & zawia hospital to assess the quality for each patient examination as, slice thickness of 2mm is (+++) it means is very good image quality but thickness of 5mm is (++) it means is good image quality.

A CT slice thickness of 2.0 mm appears optimal for liver detection using abdominal CT, as thinner reconstructions may be noise limited, resulting in artefact.

A slice thickness reconstruction <2 mm does not provide better image quality for liver due to the presence of increased noise.

Its value can be selected by the operator according to the clinical requirement and generally lies in the range between 1mm and 10mm. In general, the larger the slice thickness, the greater the low

contrast resolution in the image; the smaller the slice thickness, the greater the spatial resolution. If the slice thickness is large, the images can be affected by artefact, due to partial volume effects; if the slice thickness is small (e.g. <2mm), the images may be significantly affected by noise.

CT image quality as in most imaging, is described in terms of contrast, spatial resolution, image noise, and artefacts. A strength of CT is its ability to visualize structures of low contrast in a subject, a task that is limited primarily by noise and is therefore closely associated with radiation dose. This means the higher the dose contributing to the image, the less apparent is image noise and the easier it is to perceive low-contrast structures.

Spatial resolution is ultimately limited by sampling, but both image noise and resolution are strongly affected by the reconstruction filter.

As a result, diagnostically acceptable image quality at acceptable doses of radiation requires appropriately designed clinical protocols, including appropriate kilovolt peaks, amperages, slice thicknesses, and reconstruction filters.

Recommendations

The main issue within radiology today is how to reduce the radiation dose during CT examinations without compromising the image quality. Generally, a high radiation dose results in high-resolution images, while a lower dose leads to increased image noise and results in unsharp images. Unfortunately, as the radiation dose increases, so does the associated risk of radiation induced cancer a four phase CT abdomen gives the same radiation dose as 300 chest X-rays. However, there are several methods that can be used in order to lower the exposure to ionizing radiation during to patients undergoing a CT scan:

1- Prior to every CT examination, evaluate the appropriateness of the exam whether it is motivated or if another type of examination is more suitable. Higher resolution is not always suitable for any given scenario, such as detection of small pulmonary masses.

2-Individualize the examination and adjust the radiation dose to the body type and body organ examined. Different body types and organs require different amounts of radiation.

3- Alternative cross-sectional imaging studies such as ultrasound and MRI should be used when they have equal diagnostic capability as an optimally performed CT examination.

4-It is encouraged to use new software technology which can significantly reduce the radiation dose. The software works as a filter that reduces random noise and enhances structures.
5-It is highly advisable for all CT units to use the appropriate radiation protection devices such thyroid Colures, breast and gonad shields whenever it is possible.
6-Limiting the number of slices to the requested clinical area without missing any vital anatomical regions, instead of having wider views which will deliver higher unnecessary patient radiation doses.
7-Encouraging more research projects in the field of radiation dose reductions in all aspects of X-ray imaging procedures in Libyan hospitals and private clinics in order to lower the general population doses.

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