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Difference between volume Computed Tomography Dose Index (CTDIvol) and Size-Specific Dose Estimates (SSDE) in abdomen- and thorax protocols in patients of different sizes in different CT scanners

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Difference between volume Computed Tomography Dose Index (CTDIvol) and Size-Specific Dose Estimates (SSDE) in abdomen- and thorax protocols in patients of different sizes in different CT scanners

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Abstract

Background: Volume Computed Tomography Dose Index ($CTDI_{vol}$) only provides information about the radiation dose delivered by a CT scanner. The Size Specific Dose Estimate (SSDE) introduced by the American Association of Physicists in Medicine (AAPM) takes into account patient size and gives a more accurate representation of received radiation doses. The aim of the study is to examine the difference between $CTDI_{vol}$ and estimated SSDE values in thoracic and abdominal scans in different CT scanners and investigate the level of under- or overestimation of doses in patients of various sizes.

Methods: Retrospective data collection included 500 thoracic scans and 500 abdominal scans from four different scanners from two separate vendors. Age, $CTDI_{vol}$, AP- and LAT-diameter were gathered from the Picture Archiving and Communication System (PACS), effective diameter ($D_{eff)}$, and water equivalent diameter ($D_{w)}$ were calculated in Excel. A t-test was used to determine if there was a statistically significant difference between $CTDI_{vol}$ and estimated SSDE.

Results: In all scanners, there was a statistically significant difference between $CTDI_{vol}$ and estimated SSDE values ($p < 0.05$). In abdominal scans, the under- or overestimation of doses ranged from 41% in patients with a D_{eff} of 18-21.9 cm to -14% in patients with a D_{eff} of 38-41.9 cm. In the thoracic scans, the underestimation of doses ranged from 43% in patients with a D_w of 18.-21.9 cm to 6% in patients with a D_w of 34-37.9 cm.

Conclusion: By taking into account the patient size and the scanner output, we found that CTDIvol underestimates radiation doses to patients of small sizes (<32 cm) and overestimates doses to some, but not all, larger patients (>32 cm).

Sammendrag

Bakgrunn: Volum Computed Tomography Dose Index ($CTDI_{vol}$) gir kun informasjon om hvor mye stråling som kommer ut av CT-skanneren til et gitt snitt ved en gitt protokoll, og tar ikke hensyn til pasientspesifikke parameter slik som pasientstørrelse eller attenuasjon i pasienten. Size Specific Dose Estimate (SSDE), som ble introdusert av American Association of Physicists in Medicine (AAPM), tar hensyn til pasientstørrelse og attenuasjon i pasienten og vil derfor gi et bedre mål på hvilken dose den enkelte pasient har mottatt. Målet med studien er å undersøke forskjellen mellom $CTDI_{vol}$ og estimert SSDE-verdi for CT thorax og CT abdomen for forskjellige CT-skannere og undersøke hvor mye under- eller overestimering av doser man får for pasienter av ulike størrelser.
Metoder: Retrospektiv datainnsamling inkluderte 500 CT thorax og 500 CT abdomen fra fire forskjellige skannere fra to ulike leverandører. Alder, $CTDI_{vol}$, AP- og LAT-diameter ble samlet fra Picture Archiving and Communication System (PACS), effektiv diameter (D_{eff}) og vannekvivalent diameter (D_w) ble beregnet i Excel. Student t-test ble benyttet for å se om det var en statistisk signifikant forskjell mellom $CTDI_{vol}$ og estimert SSDE.
Resultater: For alle fire skannere inkludert i studien var det en statistisk signifikant forskjell mellom $CTDI_{vol}$ og estimert SSDE-verdi ($p < 0.05$). For CT abdomen varierte under- eller overestimering av stråledoser fra 41% hos pasienter med D_{eff} på 18.0-21.9 cm til -14% hos pasienter med D_{eff} på 38.0-41.9 cm. For CT thorax varierte underestimeringen av stråledoser fra 43% hos pasienter med en D_w på 18.0-21.9 cm til 6% hos pasienter med en D_w på 34.0-37.9 cm.
Konklusjon: Ved å ta hensyn til pasientstørrelse og skannerutgang, fant vi at $CTDI_{vol}$ underestimerer stråledoser til pasienter mindre enn <32 cm i effektiv diameter og overestimerer stråledoser til noen, men ikke alle, pasienter med effektiv diameter større enn >32 cm.

List of abbreviations

AAPM	American Association of Physicists in Medicine
ALARA	As Low as Reasonably Achievable
AP	Anterior-Posterior
ATCM	Automatic Tube Current Modulation
CT	Computed Tomography
CTDI	Computed Tomography Dose Index
D_{eff}	Effective Diameter
DLP	Dose Length Product
DNA	Deoxyribonucleic acid
DRL	Diagnostic Reference Levels
D_w	Water Equivalent Diameter
HU	Hounsfield Unit
ICRP	International Commission on Radiological Protection
kVp	kiloVolt peak
LAT	Lateral
LNT	Linear No Threshold
mAs	milliamper per second
mSv	milli Sievert
PMMA	Polymethyl Methacrylate
ROI	Region of Interest
SFOV	Scan Field of View
SSDE	Size Specific Dose Estimate
TCM	Tube Current Modulation

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Introduction

1. Computed Tomography

Computed Tomography (CT) is a medical imaging technology that has transformed the field of imaging in medicine by providing three-dimensional views of organs. Computed Tomography uses x-rays and detectors which move around the patient to gather different coefficients from different tissues to create an image.

A CT scanner creates images by directing an x-ray beam onto the patient and measuring the attenuated x-rays in the detector. The attenuation response is then transmitted to a computer which analyzes the signal and reconstructs an image to display on a monitor. Mathematical equations adapted for computer processing are used to reconstruct the cross-sectional anatomy [1].

In 1972, Godfrey Hounsfield built the first commercial medical CT scanner. The scanner had an x-ray tube and two detector elements which moved around the patient in a step-by-step motion. A demonstration of these elements can be seen in Figure 1. The scanner was able to acquire twelve slices with 13 mm thickness each and reconstruct the images with a matrix of 80x80 pixels in roughly 35 minutes [2].

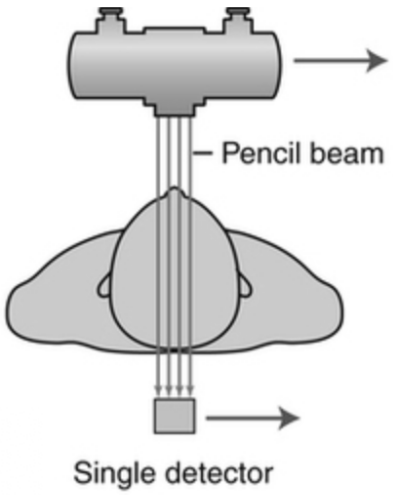

Figure 1. First generation CT scanner elements.

In the second-generation CT scanners, the units incorporated an extension of the single detector to a multiple detector assembly that changed the x-ray beam's shape to a fan-shaped beam instead of the pencil beam. The advantage of the second generation compared to the first was the speed, because shorter acquisition times were possible with the increased number of detectors [1].

Modern CT scanners are primarily of the "third-generation". They are comprised of an x-ray tube and detector that are mounted to a rotating gantry which rotate around the patient simultaneously, a demonstration of these elements can be examined in Figure 2. The evolution of the rotational motion is the most crucial factor in the decrease in acquisition times, which has been reduced from minutes to less than a second since the first CT scanner. A modern CT detector has 700 or more detector elements in the beam direction covering a Scan Field of View (SFOV) of typically 50 cm in diameter.
It creates images by measuring attenuation values in the individual detector elements, the measurements acquired from the same angular position then form a projection. About a thousand projections are measured in each gantry rotation [2].

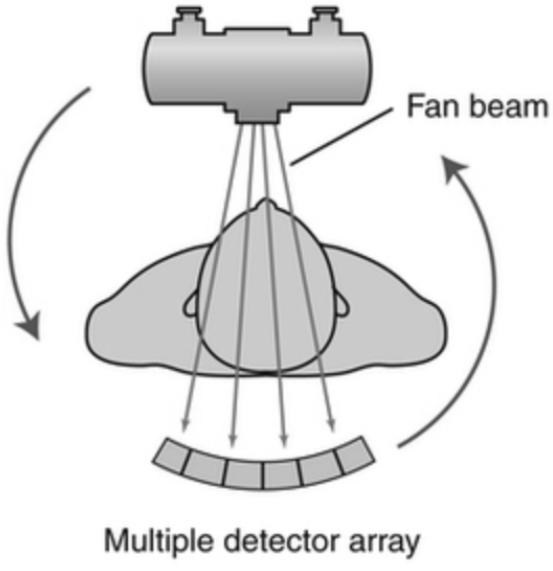

Figure 2. Third generation CT scanner elements.

Since Hounsfield built the first CT scanner, Computed Tomography has become a staple in medical imaging and diagnostics in modern clinical work. It can create views of organs in each plan and give valuable information about organ activity in some cases. However, CT

results in radiation exposure to the patient, which needs to be considered each time a patient is scanned.

2. Ionizing radiation

As Wilhelm Roentgen was unaware of at the time, x-rays produce ionizing radiation, which can cause stochastic or deterministic effects in the human body [1].
After the adoption of CT as a clinical modality, concerns on radiation doses quickly became an issue.

Radiation merely describes particles or waves of high enough energy to pass through matter. The interactions that can be responsible for biological changes occur when the radiation ionizes an atom that it interacts with. Ionization means that an interaction between an electron and an x-ray has taken place, leading to the complete removal of an electron from its atom. The positively charged atom that is left behind is then in an unstable state. This process can be the first step towards many biological changes in cells, making each exposure to ionizing radiation a risk to the individual being exposed, directly or indirectly [3].

As stated before, ionizing radiation can cause either stochastic or deterministic effects on human cells. Stochastic effects have no direct relationship to dose. They are random in nature and can happen at any dose level. The probability of the effect occurring depends on the amount of radiation, the effect increases as the dose increases, and there is no threshold.
On the other hand, deterministic effects are caused by radiation doses of certain levels and are often caused by direct cell death. They have a threshold dose and include skin burns, hair loss, tissue damage, and organ dysfunction. The severity of the damage increases with the dose. Whereas in stochastic effects, the probability of damage increases with dose. Stochastic effects develop over time, where DNA damage can turn into cancer, leukemia, or other genetic effects [4].

The International Committee on Radiation Protection (ICRP) uses a linear no threshold model as a reference to describe the effects of ionizing radiation on the human body [5]. According to the Linear No-Threshold (LNT) model, the risk is proportional to the dose, and there is no threshold. The LNT model is open to much debate since there is very little

evidence to support radiation effects below 100 mSv [3]. A demonstration of the model can be seen in Figure 3.

The LNT model is based on the fact that we have evidence for risks associated with high-dose levels of radiation, and because of that, we try to calculate risks associated with lower doses. The „No-Threshold" part of the model means that it assumes there is no "safe" level of radiation [3].

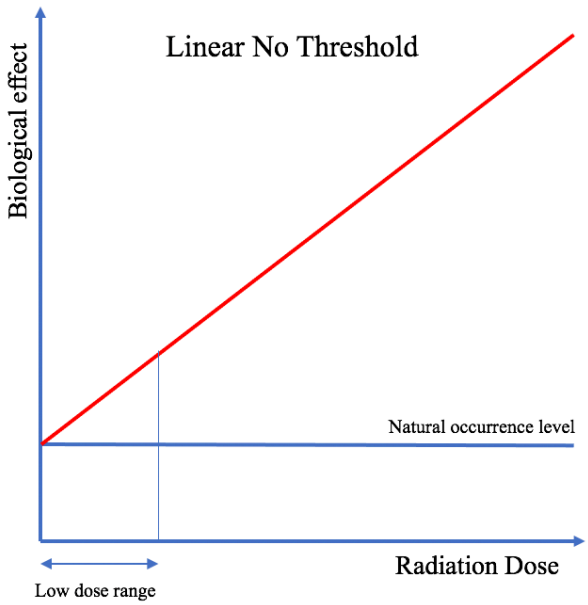

Figure 3. Demonstration of the Linear-No-Threshold model.

Some factors influence the risk of stochastic and deterministic effects at low-dose exposures, including radiosensitivity of the cell, kinetics, presence of oxygen, and dose rate.

Because stochastic effects often appear long after radiation exposure, it is hard to determine if it is a consequence of radiation or something else entirely [3].

In their research from 2007, Brenner and Hall [6] concluded that "risk projection models for radiation-induced carcinogenesis estimate that in a few decades, 1,5-2% of all cancers in the United States may be attributable to the use of CT".

An epidemiological study by Pearce et al. in 2012 [7] about radiation exposure from CT in childhood resulted in 3 powerful conclusions:

- There is a risk of cancer from diagnostic x-ray exposures
- This risk is very low

- The risk, although low, is detectable, so statements that radiation risks associated with diagnostic exposures are simply undetectable must be questioned.

Based on the LNT model, the ICRP released a framework in 2007 [5], which includes a principle of optimization of protection; As Low as Reasonably Achievable, the ALARA principle is well established by personnel working with ionizing radiation. It assumes that there is no "safe zone" in medical imaging with radiation. Every time a patient is exposed to x-rays, the dose should be kept as low as possible without jeopardizing acceptable image quality, ensuring that the benefit of the examination outweighs the potential risk [3].

3. Radiation in Computed Tomography

Because the radiation kV peak has to be high enough to penetrate through the body without scattering in the tissue, computed tomography examinations contribute to relatively high radiation doses to patients compared to other traditional imaging methods, or 60 to 70% of all medical imaging radiation [8,9]. Although doses will generally not result in effective doses higher than 100 mSv, which is the mark where radiation risk becomes deterministic, there is always a risk of stochastic effects. It is important to be aware of radiation doses in CT and be familiar with the different dose descriptors that are essential tools in daily clinical work.

3.1 CTDI

CTDI is an abbreviation for Computed Tomography Dose Index and is a standardized measurement of the radiation dose output per slice.
The $CTDI_{100}$ was developed to extend the length of the scan measurement.
A 100mm pencil ion chamber is used to measure the integrated dose profile along the scanner axis and the dose to the phantom. It is estimated by weighting $CTDI_{100}$ in the center of the phantom and on the peripheral sides. A $CTDI_w$ is weighted to account for the average dose in the x-y axis of the patient instead of the z-axis and represents the average CTDI in the scan plane [10].
The Volume Computed Tomography Dose Index ($CTDI_{vol}$) varies with mAs, kVp, and changes with helical pitch. Most scanners use a 32 cm diameter phantom for body protocols and a 16 cm diameter phantom for head and pediatric protocols. The $CTDI_{vol}$ takes into account the effect of pitch and can be calculated with the following formula:

$$\mathbf{CTDI_{vol} = CTDI_{w} / Pitch}$$

The CTDI value that is shown on the scanner before the helical scan, is weighted, but after the scan, $CTDI_{vol}$ can be shown by estimating output dose in the spiral scan after being corrected for pitch [10].

3.2 DLP and pitch

CTDIvol by itself is independent of the scan volume and therefore does not give us information on the dose to the patient.

The DLP: Dose Length Product, incorporates the scan length.

DLP = Length * $CTDI_{vol}$

With both $CTDI_{vol}$ and the DLP value, the effective dose to the patient can be estimated.

In a helical scan, the table moves while the gantry rotates. The pitch describes how much of the patient is scanned in accordance with the table movement.

If the pitch is =1, then the gantry rotation is equal to the x-ray beam width. If the pitch is <1, it will result in overlapping scans. And if the pitch is >1, there will be gaps in the scan that can cause artifacts.

Increasing the pitch reduces the dose, but that is not an optimal way to reduce patient dose, as the automatic exposure control will simply increase the tube current [11].

3.3 Size Specific Dose Estimate

In 2011, the American Association of Physicists in Medicine (AAPM) introduced a new dose descriptor, the size specific dose estimate (SSDE), which takes into account the size of each patient. Because not everyone is either 32 cm or 16 cm in diameter like the phantoms that are used to calculate $CTDI_{vol}$.

The SSDE is estimated by using generated conversion factors which take into account the patient size [12].

The effective diameter (D_{eff}) represents the patient diameter at one location in the z-axis of the patient and assumes that the patient has a circular cross-section. The effective diameter is directly proportional to a diameter of a circle whose area is the same as that of the patient cross-section. It can be found by measuring the antero-posterior and lateral diameter of the given location in the z-axis and then using a formula that combines the two values into one. Using the effective diameter, the output dose from the scanner ($CTDI_{vol}$), and specific conversion factors from AAPM report 204, the SSDE can be estimated [12].

Since this method was established, a water-equivalent diameter (D_w) was also introduced to more accurately describe the patient attenuation, taking into account the different compositions of tissues in the areas being scanned.
The water equivalent diameter takes into account the physical dimensions of the patient along with the attenuation values [13].

The SSDE dose descriptor has been validated in several studies, using both cadavers and phantoms. However, the adoption of SSDE in clinical practice is dependent on CT scanner manufacturers to implement methods to automatically calculate and report the SSDE [14]. Even though the AAPM has proved SSDE to be a more accurate descriptor of the actual patient dose than $CTDI_{vol}$, there are some downsides to SSDE. Even when size is taken into account, the actual radiation dose to any given patient may differ from the calculated values when using the conversion factors from AAPM report no.204 by 10%-20% [12]. SSDE is also limited to an estimation of the dose at the center of a CT range, and does not take into account different variations in scan length. Another limitation of SSDE is that it can only be accurate when patients are centered in the CT gantry so that magnification effects are minimized [15].

3.4 Diagnostic Reference Levels

The American College of Radiology [3] defines Diagnostic Reference Levels (DRL's) as "an investigation level to identify unusually high radiation dose or exposure levels for common diagnostic medical x-ray procedures". The doses are based on the third quartile of representative doses for a given examination.
DRL's are tools that x-ray imaging departments can use to measure and administer radiation doses to patients. If doses are continuously higher than established DRL's for a given country, a department should be concerned and look into making changes in their radiation protection procedures and investigate why exposures are beyond the DRL's.
The average DRL's for abdomen and thorax examinations in Europe are 25 mGy and 10 mGy, respectively [16].

4. Dose modulation techniques

With the implementation of automatic tube current modulation (ATCM), the radiation doses have changed so that not every patient gets the same output dose from the scanner. The ATCM can calculate how much radiation is needed to create an acceptable image quality scan of a specific patient [17].
All modern CT scanners are equipped with TCM (mA modulation), which represents an effective method to reduce the radiation to a patient. But vendors have now started to include automatic kV-selection, as well as organ dose modulation techniques [2].

4.1 Automatic Tube Current Modulation

ATCM automatically modulates the tube current (mA), and thereby the radiation dose throughout the scan in the x-, y- and z-direction, and is now very common in all CT scanners. In large patients, TCM increases the tube current (mA) and consequently the x-ray exposure to preserve the number of detected photons in different attenuating tissues.
TCM is vital for both radiation dose determination and the image quality outcome, so understanding its behavior is essential. ATCM automatically controls the tube current during the data acquisition by measuring the patient's size and the attenuation differences of various tissues [17,18].

4.1.2 Tube current modulation and automatic kV selection in Siemens

CARE Dose 4D is a reference milliamperage-based ATCM, which evaluates the patient cross-section being scanned and changes the tube current relative to a reference effective milliamperage. It aims to provide acceptable image noise for each patient, based on the principle that patients of different sizes require different noise levels to maintain acceptable image quality. A consequence is that Siemens has set up their system to allow for increasing noise level with increasing patient size. A reference effective milliamperage is designed for an average-sized patient. The scanner then reduces the reference effective milliamperage in small patients and increases it for larger patients [19].
CARE Dose 4D aims to keep image quality the same for every patient.

Care kV is an automatic tube potential selection that works in combination with *CARE Dose 4D*. Automatic tube potential selection is an automatic exposure control (AEC) method that

can select the tube potential for a specific diagnostic task according to patient size and achieve desired image quality at a lower $CTDI_{vol}$ [20].

4.1.3 Tube current modulation and automatic kV selection in Canon

Sure-Exposure 3D from Toshiba/Canon is a standard deviation-based ATCM, where users must select a standard deviation of a pixel value for desired image quality. A high standard deviation will result in noisy images, and low standard deviation values will result in less noisy images. Sure-Exposure 3D aims to keep the same noise level in the images for every patient, independent of their size, by using a reference position for a given region and the mean attenuation within the scanning area to calculate the tube current. The system uses information from pre-scan images to determine the tube current in each rotation [19].

Sure kV from Toshiba/Canon modulates the tube voltage (kV) based on the patient's attenuation profile from the pre-scan images and the planned examination type [21].

5. Recent Literature

The AAPM has contributed significantly to the development of the SSDE research and has demonstrated how to apply it and proven it to be a more accurate descriptor for patient dose, compared to $CTDI_{vol}$.

In their report no. 204 (2011), the AAPM task group presented the SSDE as a new dose descriptor and published generated conversion factors for estimating the SSDE from $CTDI_{vol}$ values and the patient's effective diameter. The report also included guidelines on how to use SSDE in clinical work [12].

In report no. 220 (2014), they cover the use of water equivalent diameter for calculating the patient size and the SSDE. They concluded that using the effective diameter to estimate SSDE for thoracic scans would lead to an overestimation of patient attenuation and an underestimation of SSDE, and introduced the water equivalent diameter, which takes into account the amounts of air in the lungs [13].

Report no. 293 (2019) addresses the SSDE for head CT, along with more detailed directions in the use of SSDE as a dose descriptor [14].

Franck C et al. (2015) found that using the SSDE helped with estimating accurate patient-specific organ- and blood doses, and LAR (Lifetime Attributable Risk) estimation in routine clinical practice [22].

Anam C et al. (2016) proposed an algorithm for automated calculation of D_{eff} (Effective Diameter), D_w (Water Equivalent Diameter), and SSDE. They also found that in thoracic examinations, the radiation dose (SSDE) decreases with decreased patient diameter when Tube Current Modulation is activated [23].

Anam C, F Haryanto, and colleagues (2018) developed a specific calculator for estimating $CTDI_{vol}$ and SSDE in a CT scanner equipped with the TCM technique [10].

Bashier EH. and Suliman II. (2018) compared radiation exposures based on SSDE in Sudanese hospitals and found that the correlation between the patient size and dose based on scout images was less significant than that based on transverse images. However, they concluded that further studies are needed to improve the patient dose data in CT using the water equivalent diameter [24].

Barreto et al. (2020) looked into the effect of TCM on SSDE and concluded that SSDE takes into account the size of the patient and provides a more accurate reflection of patient dose than $CTDI_{vol}$ [25].

To our knowledge, there is a limited number of studies that look into the under- or overestimation of doses in CT when using $CTDI_{vol}$ as a dose descriptor.
Researchers have looked into the effects of various factors on SSDE and examined the accuracy of SSDE, but there seems to be a gap in the research field where the dose descriptors are assessed in a broader aspect. Our literature search did not find many studies comparing different vendors regarding accuracy in dose reporting.

6. Purpose of the study

Volume Computed Tomography Dose Index ($CTDI_{vol}$) only provides information about the radiation dose from the CT scanner and thus underestimates the doses from smaller patients by a factor of 2-3 (for a 32cm PMMA phantom) [4]. The $CTDI_{vol}$ does not take into consideration the patient size and is therefore not a good estimate for the patient dose because the dose that a patient receives from a CT scanner depends on the radiation output, the patient's size, and the attenuation in the patient's body [26].
The Size Specific Dose Estimate (SSDE) does however include the patient size and the CT scanner output to estimate the dose received by the patient more accurately.

The aim of the study is to look at the difference between reported $CTDI_{vol}$ and estimated SSDE values in thoracic and abdominal scans in different CT scanners and investigate the level of under- or overestimation of doses in patients of different sizes. In addition, we compared the two different vendors included in the study and investigated if there was a significant difference between the scanners when it comes to under- and overestimating the patient dose.

Radiation protection is a significant part of daily clinical work in medical imaging, and an aspect of radiation protection is the dose reporting. Having accurate dose reports would be beneficial for many factors like staying below DRL's, communicating the risk to worried patients, understanding the effects of different modulation techniques, and using the correct protocols for patients of various sizes, particularly children.
Estimating radiation doses accurately is desirable in daily clinical work due to the constant aim to keep doses as low as reasonably achievable.
The end goal is to get a better insight into the upsides and downsides of the two dose descriptors and aid in the evaluation of which dose descriptor would be most suitable to ensure the best possible method for dose reporting.

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Article manuscript

Difference between volume Computed Tomography Dose Index (CTDIvol) and Size-Specific Dose Estimate (SSDE) in abdomen- and thorax protocols in patients of different sizes in different CT scanners

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Difference between volume Computed Tomography Dose Index ($CTDI_{vol}$) and Size-Specific Dose Estimates (SSDE) in abdomen- and thorax protocols in patients of different sizes in different CT scanners

H.P. Birnisdottir

Background: Volume Computed Tomography Dose Index ($CTDI_{vol}$) only provides information about the radiation dose delivered by a CT scanner. The Size Specific Dose Estimate (SSDE) introduced by the American Association of Physicists in Medicine (AAPM) takes into account patient size and gives a more accurate representation of received radiation doses. The aim of the study is to examine the difference between $CTDI_{vol}$ and estimated SSDE values in thoracic and abdominal scans in different CT scanners and investigate the level of under- or overestimation of doses in patients of various sizes.
Methods: Retrospective data collection included 500 thoracic scans and 500 abdominal scans from four different scanners from two separate vendors. Age, $CTDI_{vol}$, AP- and LAT- diameter were gathered from the Picture Archiving and Communication System (PACS), effective diameter ($D_{eff)}$, and water equivalent diameter ($D_{w)}$ were calculated in Excel. A t-test was used to determine if there was a statistically significant difference between $CTDI_{vol}$ and estimated SSDE.
Results: In all scanners, there was a statistically significant difference between $CTDI_{vol}$ and estimated SSDE values ($p < 0.05$). In abdominal scans, the under- or overestimation of doses ranged from 41% in patients with a D_{eff} of 18-21.9 cm to -14% in patients with a D_{eff} of 38-41.9 cm. In the thoracic scans, the underestimation of doses ranged from 43% in patients with a D_w of 18.-21.9 cm to 6% in patients with a D_w of 34-37.9 cm.
Conclusion: By taking into account the patient size and the scanner output, we found that CTDIvol underestimates radiation doses to patients of small sizes (<32 cm) and overestimates doses to some, but not all, larger patients (>32 cm).

Keywords: Computed Tomography (CT), Volume CT Dose Index ($CTDI_{vol}$), Size Specific Dose Estimate (SSDE), Effective Diameter (D_{eff}), Water-Equivalent Diameter (D_w)

Introduction

Computed Tomography has transformed the field of imaging in medicine by providing three-dimensional views of organs, contributing to approximately 60 to 70% of all medical imaging radiation [1, 2]. With increased use of the modality, [3, 4] concerns rise on the potential carcinogenic effects from repeated low radiation doses [5, 6]. The Computed Tomography Dose Index (CTDI) is the dose descriptor used to describe the radiation dose and gives us a measurement of CT x-ray tube radiation output, but it is not a stand-alone metric for patient dose [7]. The Volume CTDI ($CTDI_{vol}$) underestimates the doses from smaller patients by a factor of 2-3 (for a 32 cm PMMA phantom) [3].

The dose that a patient receives from a CT scanner depends on the patient´s size, the attenuation in the patient, and the radiation output from the scanner [7]. Therefore, $CTDI_{vol}$ can not be considered suitable for estimating the correct patient dose as it does not take into account the patient size.

In 2011, the American Association of Physicists in Medicine (AAPM) presented a new dose descriptor, the Size-Specific Dose

Estimate (SSDE), which takes into account the patient‘s size, through conversion factors, and is a more accurate descriptor of the absorbed dose in patients of different sizes [3].
The estimation of SSDE can be performed by measuring the anterior-posterior (AP) and lateral (LAT) diameter of a patient‘s cross-section and estimate an effective diameter (D_{eff}). The effective diameter can then be used to find the appropriate conversion factors from the AAPM report no.204 and estimate the SSDE.
In ICRU report 87 [8], it is recommended that a water-equivalent diameter (D_w) is used when estimating SSDE from CT thorax examinations instead of the effective diameter because of the amounts of air in the lungs, which needs to be accounted for. The larger proportion of air in the lungs compared to other tissues leads to a smaller tissue mass and thus lesser attenuation of x-rays.
The outer physical dimensions of the patient are therefore not sufficient for data estimation in thoracic scans [9]. Barreto et al. [10] suggests that the water-equivalent diameter for CT thorax examinations can be found by measuring the Hounsfield units within a freehand region of interest (ROI) around the patient’s chest in a central axial slice. The water equivalent diameter can then be used to estimate SSDE values in thoracic scans, along with the conversion factors from AAPM.

The aim of the study is to look at the difference between reported $CTDI_{vol}$ and estimated SSDE values in thoracic and abdominal scans in different CT scanners and investigate the level of under- or overestimation of doses in patients of different sizes. In addition, we compared the two different vendors included in the study and investigated if there was a significant difference between the scanners when it comes to under- and overestimating the patient dose.

Methods

Sample Size

The sample size was determined based on a statistical power analysis with a confidence level of 95%. The results of the Statistical Power Analysis were 124, hence data from 125 patients from each scanner for both abdominal and thoracic scans was gathered in the time period between September 10th and December 20th, 2020, from studies performed between May 15th, 2019, to November 20th, 2020.
Resulting in 500 thoracic scans and 500 abdominal scans.

CT scanners included in the study

Four CT scanners were involved in the study; Siemens Somatom Definition (Siemens Medical Solutions, Forcheim, Germany), later referred to as SSD. Toshiba Aquillion One, Toshiba Aquillion Prime, and Canon Aquillion One/Genesis edition (Canon Medical Systems, Ōtawara, Japan) later referred to as TAO, TAP and CAO, respectively. The scanners are located at two hospitals, the National University Hospital of Iceland (LSH) and Akureyri University Hospital (SAk).

Retrospective data collection

The data was retrospectively collected from the Picture Archiving and Communication System (PACS).
For each patient, the age and the radiation dose ($CTDI_{vol}$) were registered from the dose report and the anterior-posterior (AP) and lateral (LAT) diameter of the patient

were measured in the images with virtual calipers, which can be examined in Figure 1. In the thoracic scans, the central axial slice was selected at the lower apex of the scapula, and in the abdominal scans the central axial slice was selected at mid-kidney level.
Additionally, for each patient that underwent a thoracic CT scan, the area (cm^2) and average attenuation values (HU units) were measured in an identical axial slice. These measurements were made by drawing a freehand region of interest around the patient's chest in the same central axial slice used to measure the AP and LAT diameter, carefully excluding the patient table and other objects in the field of view (FOV). A demonstration of this process can be seen in Figure 2.

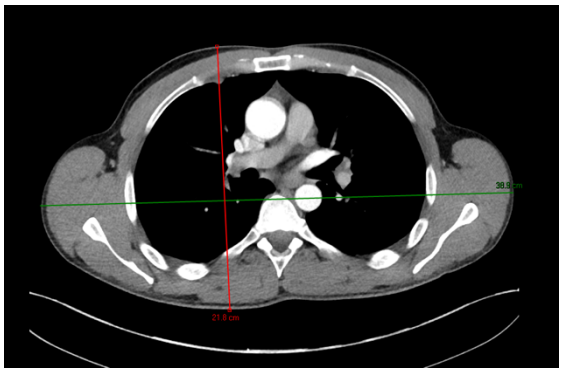

Figure 1. Virtual calipers in PACS used to measure AP and LAT diameter.

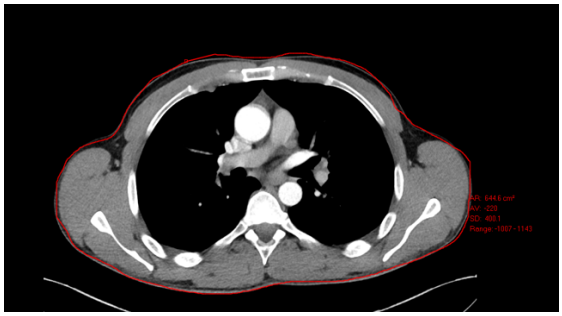

Figure 2. A freehand Region of Interest in PACS used to measure the area (cm^2) and average attenuation values (HU units).

Determination of D_{eff} and D_w
The effective diameter (D_{eff}) for each patient was calculated using the following equation:

$$\sqrt{AP\ x\ LAT}$$

Where AP represents the Anterior-Posterior diameter and LAT represents the Lateral diameter of the patient [3].

The Water Equivalent Diameter (D_w) was calculated for each patient who underwent a thoracic scan in order to compensate for the large amounts of air in the lungs, which affect the attenuation of the radiation [10].

D_w was calculated using the area (cm^2) and the average attenuation value in Hounsfield Units (HU) using the following equation [10]:

$$D_w = 2\sqrt{\left(1 + \frac{HU_{ROI}}{1000}\right)\frac{Area_{ROI}}{\pi}}$$

Determination of Size Specific Dose Estimates (SSDE)
The determination of the SSDE was calculated using the conversion factors for a 32 cm PMMA phantom [3] by the following equation:

$$SSDE = CTDI_{vol}\ x\ f$$

where *f* is the appropriate conversion factor for each diameter.

Statistical methods
Statistical analyses were conducted using SPSS for MacBook version 27 (IBM Inc,

Armonk, NY). The ShapiroWilk test was used to determine that the data was normally distributed before using a two-sample, unpaired t-test in order to see if there was a statistically significant difference between $CTDI_{vol}$ and SSDE for each of the scanners. A p value of less than 0.05 was considered to indicate a statistically significant difference.

The Pearson correlation coefficient was used to report the correlation between patient age and the percentage difference between $CTDI_{vol}$ and SSDE.

Linear regression models, including the Pearson Correlation Coefficient (R^2), were used to report the correlation between the percentage difference between SSDE and $CTDI_{vol}$, and D_w/D_{eff}, where $R^2 > 0.9$ was considered to resemble a strong statistical relationship.

Ethical Considerations

The National Bioethics Committee of Iceland approved the research (study approval number VSN-20-155) along with both hospitals involved.

This retrospective study only includes anonymous data with no information that may identify an individual, neither directly nor indirectly.

Results

The difference between $CTDI_{vol}$ and SSDE for each scanner in both thoracic and abdominal scans was statistically significant ($p < 0.05$).

The number of patients, age, effective diameter (D_{eff}), $CTDI_{vol}$, SSDE, and the percentage difference between $CTDI_{vol}$ and SSDE in abdominal scans in all four scanners are listed in Table 1.

The average difference between $CTDI_{vol}$ and estimated SSDE values in abdominal scans was 15.5 ± 12.3% in patients with an average D_{eff} of 30.7 cm.

No significant correlation was found between patient age and the difference between $CTDI_{vol}$ and SSDE (>0.05).

A large negative correlation ($R^2 > 0.9$) was observed between D_{eff} and the percentage difference between $CTDI_{vol}$ and SSDE in abdominal scans in all four scanners, which can be examined in Figure 3.

Table 1. Values from abdominal CT scans expressed as mean ± standard deviation (minimum – maximum), including p values for significance.

Scanner	n	Age	D_{eff} (cm)	CTDIvol (mGy)[1]	SSDE (mGy)[2]	% difference between [1] and [2]	p value*
Siemens Somatom Definition	125	64.03 ± 16.7 (21-96)	31.2 ± 4.1 (19.3-41)	9.1 ± 3.6 (2.6-22.5)	10.4 ± 3.15 (3-22)	13.7 ± 12.6 (-22-42)	<0.001
Toshiba Aquillion One	125	72.04 ± 15.4 (26-99)	30.3 ± 3.8 (20.7-38.5)	9.1 ± 4.5 (3.2-20.5)	10.6 ± 3.9 (5-22)	17.3 ± 11.7 (-11-47)	<0.001
Toshiba Aquillion Prime	125	69.62 ± 16.3 (24-96)	30.5 ± 4 (19.1-43.5)	8.9 ± 4.9 (2.8-27.2)	10.2 ± 4.4 (5-24)	16.5 ± 12.3 (-30-44)	<0.001
Canon Aquillion One	125	69.1 ± 14 (24-96)	30.8 ± 4 (22.4-40.7)	8.2 ± 4.4 (3.1-19.6)	9.2 ± 3.6 (5-19)	14.8 ± 12.7 (-23-38)	<0.001

*All differences were statistically significant ($p < 0.05$)

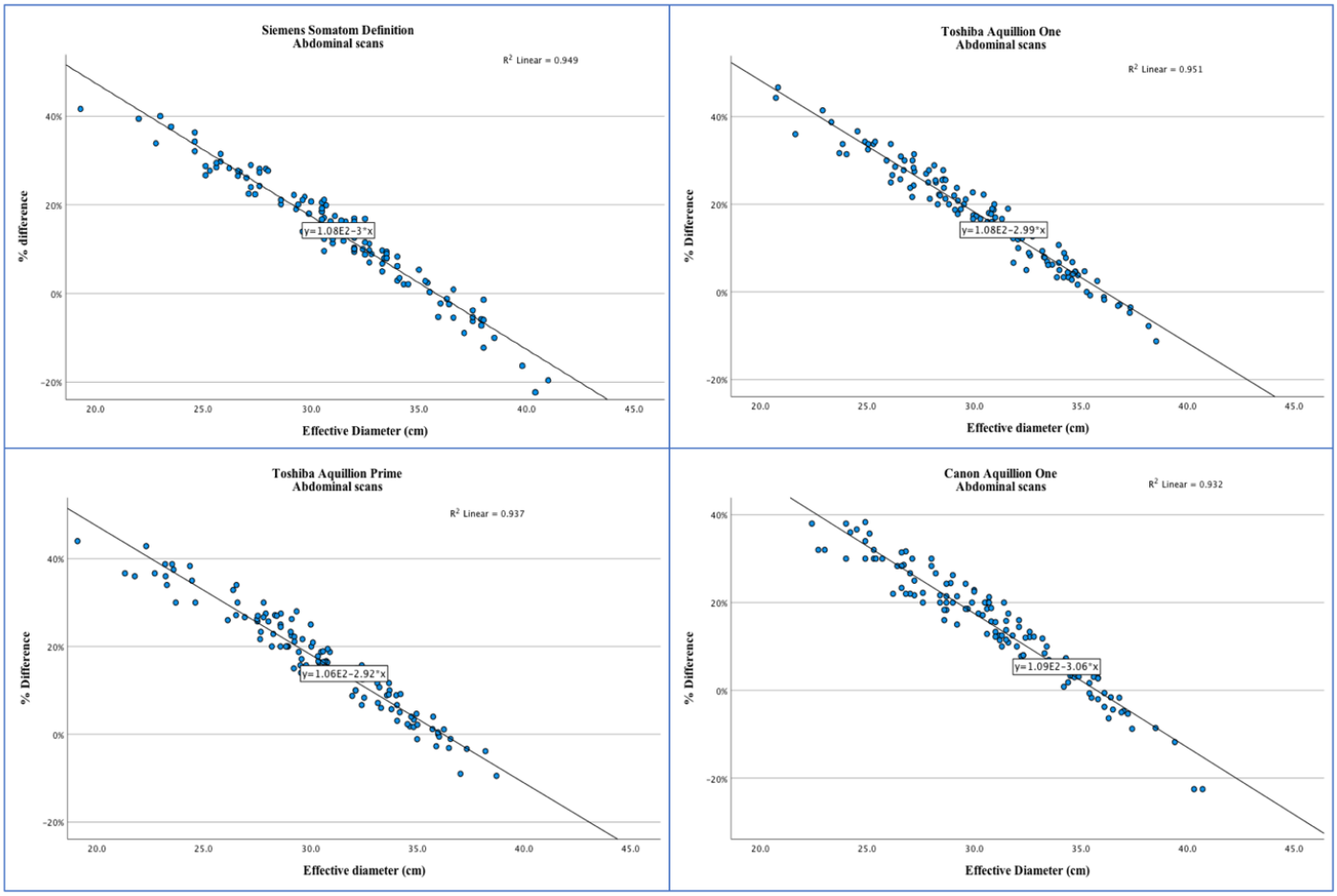

Figure 3. The relationship between patient Effextive Diameter (D_{eff}) and the percentage difference between $CTDI_{vol}$ and SSDE in abdominal scans.

The number of patients, water equivalent diameter (D_w), $CTDI_{vol}$, SSDE, and the percentage difference between $CTDI_{vol}$ and SSDE in thoracic scans in all four scanners are listed in Table 2.

Table 2. Values from thoracic CT scans expressed as means ± standard deviation (minimum - maximum), including p values for significance.

Scanner	n	Age	D_w (cm)	CTDIvol (mGy)[1]	SSDE (mGy)[2]	% difference between [1] and [2]	p value*
Siemens Somatom Definition	125	62.5 ± 15.6 (18-91)	26.2 ± 2.9 (19.6-33.9)	5.5 ± 1.7 (1.3-10.5)	7.8 ± 1.8 (1.6-12.3)	30 ± 7.5 (9-45.6)	<0.001
Toshiba Aquillion One	125	71.6 ± 15.5 (25-93)	24,9 ± 2.6 (18.2-31)	5.7 ± 2.3 (1.9 – 14.9)	8.4 ± 2.7 (3.5-19.1)	33.5 ± 6.3 (16-47.6)	<0.001
Toshiba Aquillion Prime	125	66.6 ± 15.2 (20-95)	25.9 ± 2.9 (19-33,5)	7.3 ± 4.4 (3-22)	10.3 ± 5.8 (4.9-32)	30.9 ± 7.7 (9-45.6)	<0.001
Canon Aquillion One	125	67.6 ± 18.8 (18-94)	25.6 ± 3.0 (17.1-34.8)	4.5 ± 2.4 (1.5-13.5)	6.3 ± 2.6 (2.7-14.3)	31.6 ± 7.8 (5.7-49.5)	<0.001

*All differences were statistically significant (p <0.05)

The average difference between $CTDI_{vol}$ and estimated SSDE values in thoracic scans was 31.5 ± 7.3% in patients with an average D_w of 25.6 cm.
There was a large negative correlation (R^2 >0.9) between D_w and the percentage difference between $CTDI_{vol}$ and SSDE in thoracic scans in all four scanners, which can be examined in Figure 4.

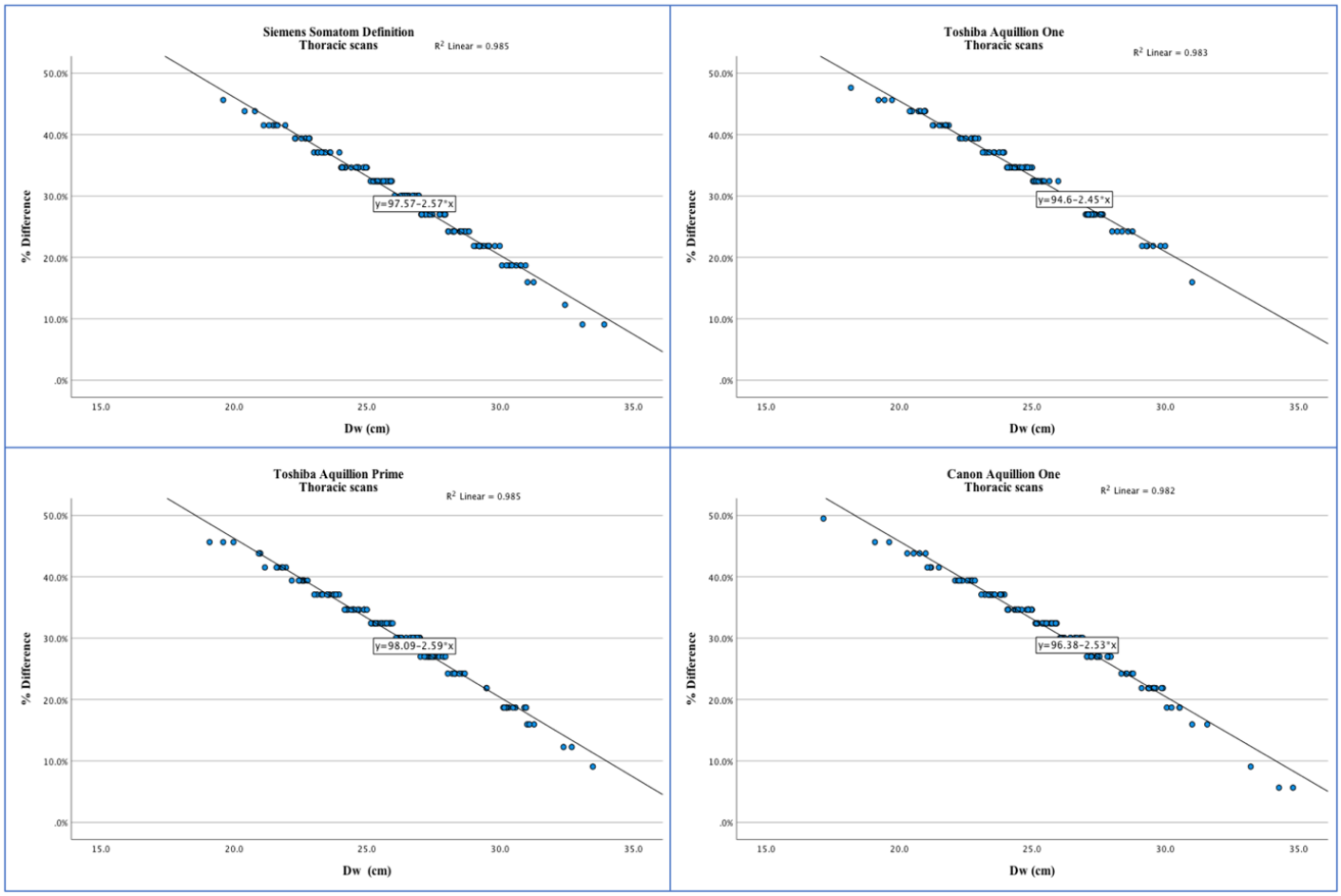

Figure 4. The relationship between water equivalent diameter (D_w) and the percentage difference between $CTDI_{vol}$ and SSDE in thoracic scans.

Patients were categorized into intervals of 4 cm each, depending on diameter, so that the difference between $CTDI_{vol}$ and SSDE can be examined for different patient sizes. In Table 3, t-tests shows that the difference is statistically significant in almost every size interval except for the 34.0-37.9 cm and 38.0-41.9 cm intervals in abdominal scans. In Table 4, t-tests show a statistically significant difference in all intervals for thoracic scans except for the 30.0-33.9 cm interval in TAO.

Table 3. Percentage differences between $CTDI_{vol}$ and SSDE including (p values) for significance in different size intervals in abdominal scans.

D_{eff} cm	18.0 - 21.9	22.0 - 25.9	26.0 - 29.9	30.0 - 33.9	34.0 - 37.9	38.0- 41.9
SSD*	42% (<0.001)	29% (<0.001)	23% (<0.001)	13% (<0.001)	-1% (0.250)	-13% (0.021)
TAO*	42% (0.023)	34% (<0.001)	25% (<0.001)	13% (<0.001)	3% (0.004)	-10% (0.079)
TAP*	39% (0.004)	36% (<0.001)	24% (<0.001)	14% (<0.001)	2% (0.065)	-14% (0.328)
CAO*	-	34% (<0.001)	23% (<0.001)	14% (<0.001)	0% (0.746)	-19% (0.023)
Avg %	**41%**	**33%**	**24%**	**14%**	**1%**	**-14%**

*SSD: Siemens Somatom Definition, TAO: Toshiba Aquillion One, TAP: Toshiba Aquillion Prime, CAO: Canon Aquillion One. (- no patient data available)

Table 4. Percentage differences between $CTDI_{vol}$ and SSDE including (p values) for significance in different size intervals in thoracic scans.

D_w cm	18.0 - 21.9	22.0 - 25.9	26.0 - 29.9	30.0 - 33.9	34.0 - 37.9
SSD*	42% (<0.001)	35% (<0.001)	26% (<0.001)	17% (<0.001)	-
TAO*	43% (<0.001)	35% (<0.001)	27% (<0.001)	19% (0.127)	-
TAP*	43% (0.010)	36% (<0.001)	28% (<0.001)	17% (<0.001)	-
CAO*	44% (<0.001)	35% (<0.001)	26% (<0.001)	17% (<0.001)	6% (0.005)
Avg %	**43%**	**35%**	**27%**	**18%**	**6%**

*SSD: Siemens Somatom Definition, TAO: Toshiba Aquillion One, TAP: Toshiba Aquillion Prime, CAO: Canon Aquillion One. (- no patient data available)

In abdominal scans, the under- and overestimation of doses ranged from 41% in patients with D_{eff} of 18-21.9 cm, to -14% in patients with D_{eff} of 38-41.9 cm.
In the thoracic scans, the underestimation of doses ranged from 43% in patients with a D_w of 18-21.9 cm, to 6% in patients with a D_w of 34-37.9 cm.

Despite the relatively small difference between scanners, one scanner had the highest percentage difference between $CTDI_{vol}$ and SSDE in both abdominal and thoracic scans.

The scanner model with the largest mean difference between $CTDI_{vol}$ and SSDE was Toshiba Aquillion One (128 slices) with a 17.3% difference in abdominal scans and a 33.5% difference in thoracic scans. The scanner with the lowest mean difference between $CTDI_{vol}$ and SSDE was Siemens Somatom Definition with a 13,7% difference in abdominal scans and a 30% difference in thoracic scans.
The only statistically significant difference between scanners in the abdominal scans was between Siemens Somatom Definition and Toshiba Aquillion One (p=0.02).

In the thoracic scans, there was a statistically significant difference between Siemens Somatom Definition and Toshiba Aquillion One ($p<0.001$), and between Toshiba Aquillion One and Toshiba Aquillion Prime ($p=0.004$).

Discussion

In all four scanners, there was an observed underestimation of radiation doses to smaller patients (<32cm) and an overestimation of doses to some of the larger patients (>32 cm) in abdominal scans. According to AAPM report 204, the $CTDI_{vol}$ underestimates doses from smaller patients by a factor of 2-3 (for a 32cm PMMA phantom)[3] which corresponds to our results as the doses to patients of smaller sizes in abdominal scans were underestimated by 14% - 41%.

In the thoracic scans, the pattern for underestimation of doses is clear in all four scanners. Because the output dose from the scanner does not account for either the patient size or composition, there was a higher mean difference between estimated SSDE values and $CTDI_{vol}$ in the thoracic scans, compared to the abdominal scans.

The most striking result to emerge from our study is the 18% difference between $CTDI_{vol}$ and SSDE in thoracic scans of patients with a D_w of 32 cm (30-33.9 cm interval). These results indicate a large underestimation of radiation doses to patients in thoracic scans, which support the claim from AAPM report 220 on the importance of considering D_w in thoracic scans because of the reduced attenuation compared to abdominal scans [11].

There was a strong negative correlation ($R^2<0.9$) between D_{eff}/D_w and the percentage difference between $CTDI_{vol}$ and SSDE in both abdominal and thoracic scans in all scanners. These results show, along with Tables 3 and 4, that the difference between $CTDI_{vol}$ and SSDE increases with decreased diameter.

The majority of the patients had an effective diameter of less than 32 cm as the average D_{eff} was 30.7 cm, and the average D_w was 25.6 cm. Hence, both average diameters were moderately smaller than the 32 cm PMMA phantom, which is used to calculate the $CTDI_{vol}$ in the scanners. Because a 32 cm PMMA phantom is used to estimate the CTDIvol, the expected result was to find a non-significant statistical difference between SSDE and CTDIvol for the 30.0-33.9 cm interval in abdominal scans. However, quite unexpectedly, our results showed a statistically significant difference between $CTDI_{vol}$ and SSDE in all size intervals except for the 34.0-37.9 cm and 38-41.9 cm intervals. In other words, the finding in this study is that the $CTDI_{vol}$ in patients with a D_{eff} in the 34.0-37.9 cm interval are the closest to estimated SSDE values.

In 2016, Yuan et al. found that doses to patients with a BMI of >24.9 (which is categorized as overweight) in abdominal scans were underestimated with a 28.4% difference. This corresponds to our results as it seems that $CTDI_{vol}$ for larger patients (>32 cm) are also being underestimated in some cases [12]. However, our results show that in patients with a D_{eff} of >38 cm, the doses start becoming overestimated, which is consistent with the nature of the conversion factors from AAPM report 204 [3].

In the thoracic scans, the difference between $CTDI_{vol}$ and SSDE was statistically significant in all size intervals except for one, the 30.0-33.9 cm interval in Toshiba Aquillion One. These results indicate a higher level of underestimation of doses in thoracic scans as the difference was

significant for almost every patient, regardless of size.

Out of the four different scanners, Toshiba Aquillion One reported $CTDI_{vol}$ values that underestimated the doses the most. As can be seen in table 1 and 2, the scanner had the highest percentage difference between reported $CTDI_{vol}$ and estimated SSDE (17.3% in abdominal scans and 33.5% in thoracic scans). Siemens Somatom Definition reported $CTDI_{vol}$ values closest to the estimated SSDE (13.7% in abdominal scans and 30% in thoracic scans).
The difference between the two vendors could lie in the fact that they each use different techniques for tube current modulation. Siemens uses a reference milliamperage based modulation to ensure acceptable image quality in all patients and adjusts the tube current in each rotation. In contrast, Canon uses a standard-deviation based modulation to deliver images with the same noise levels [13].

Although SSDE seems to be a step in the right direction when it comes to a more accurate description of patient dose, SSDE is not without flaws and must be recognized as estimates only. Even when the patient‘s size and attenuation is taken into account, the actual dose to any given patient may differ from the calculated values by 10%-20% when using the conversion factors from AAPM report no.204 [3].

Limitations:
The fact that only one scanner from Siemens is being compared to three scanners from Canon/Toshiba is limiting for the comparison of the vendors. While that was not the main adjective of this study, a more comprehensive comparison of CT vendors would be interesting and beneficial to the clinical adoption of more accurate dose descriptors.
The SSDE does not correct for differences in the organ dose distribution. Therefore, the estimation of effective dose is beyond the scope of this study.

Conclusion

The main purpose of this study was to look at the difference between reported $CTDI_{vol}$ and estimated SSDE values in thoracic and abdominal scans and investigate the level of under- or overestimation of doses in patients of different sizes.
Our findings suggest that $CTDI_{vol}$ in modern CT scanners underestimates radiation doses to patients of smaller sizes and overestimates doses to some larger patients. This implies that SSDE could be a step in the right direction for reporting patient doses by taking into account the patient size and the scanner output.

We believe our results may deliver an insight into the limitations of using $CTDI_{vol}$ to describe patient dose, and that further studies will aid in an implemention of more accurate dose descriptors to simplify dose reporting in daily clinical work.

Conflict of interest
None.

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Appendix 1: Author Guide – Radiography

https://www.elsevier.com/journals/radiography/1078-8174/guide-for-authors#txt2001

Appendix 2: Definition of terms

HU in a ROI – Attenuation values (Hounsfield Units) in a Region Of Interest in a CT image.

PMMA phantom – Uniform phantom made of Polymethyl Methacrylate used to calculate output dose from a CT scanner.

f - conversion factors for a 32 cm phantom from AAPM report 204.

FOV – Field of View is the distance over which an image is acquired.

Pearson correlation coeffecient – A measure of linear correlation between two sets of data

Strong negative correlation – Two variables have an inverse statistical relationship

Appendix 3: List over materials

CT Scanners:
Siemens Somatom Definition, 128 slices. *Siemens Medical Solutions, Forcheim, Germany*. Located at Akureyri University Hospital.
Toshiba Aquillion One, 128 slices. *Canon Medical Systems, Ōtawara, Japan.* Located at the National University Hospital of Iceland, Fossvogur Reykjavík.
Toshiba Aquillion Prime, 80 slices. *Canon Medical Systems, Ōtawara, Japan.* Located at the National University Hospital of Iceland, Fossvogur Reykjavík
Canon Aquillion One/Genesis edition, 640 slices. *Canon Medical Systems, Ōtawara, Japan.* Located at the National University Hospital of Iceland, Hringbraut Reykjavík.
Software:
Picture Archiving and Communication System, *Carestream Health*, Rochester, New York, United States.
SPSS "Statistical Package for the Social Sciences" for MacBook version 27, *IBM Inc*, Armonk, New York, United States.
Excel for macOS 10.14. *Microsoft Corporation*, Redmond, Washington, United States

Appendix 4: Patient data exclusion criteria

Excluded	**Reason**
Patients <18 years old	Only adult patients were involved in the study.
Patients unable to place their hands above their head during data aqcuisition	Increased radiation attenuation and difficulties in estimating SSDE.
Patients who exceed >45 cm in AP diameter measurements	Difficulties in estimating SSDE as conversion factors are only available for <45 cm.
Patients with amounts of implants or other metal objects in the FOV	Increased radiation attenuation and difficulties in estimating SSDE.

Appendix 5: License from the National Bioethics committee of Iceland

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VÍSINDASIÐANEFND
Borgartúni 21 - 4. hæð
105 Reykjavík,

Sími: 551 7100

netfang: vsn@vsn.is www.vsn.is

Oslo University Hospital
Ingrid Hauge, Medical physicist
inheha@ous-hf.no

Reykjavík 29. september 2020
Reference: VSNb2020090011/03.01

Subject: 20-155 - Difference between CTDIvol and size-specific dose estimates (SSDE) for abdomen-protocol and thorax--protocol for persons of different sizes for different CT-scanners

At its meeting of September 29th 2020 the National Bioethics Committee discussed your application, concerning the research project, no. VSN-20-155, *" Difference between CTDIvol and size-specific dose estimates (SSDE) for abdomen-protocol and thorax--protocol for persons of different sizes for different CT-scanners".*

Your research collaborator is Hugrún Birnisdóttir, master degree student.

Stated in chapter B1 in your Application is:

„Men and women of different sizes that have received CT thorax and CT abdomen examinations. The data that are to be collected are not patient specific. It is not possible to identify the patient with regards to the data that are going to be collected. The data will be collected retrospectively." Data will be gathered from SAk, Akureyri Hospital and Landspítali háskólaskjúkrahús.

Stated in Chapter B2 is:

„The following data needs to be gathered:

- *For each patient the AP and LAT diameter must be measured*
- *For each patient the CTDI needs to be written down*
- *For each patient the age will be recorded*
- *If a note of the weight is available, this could be of interest too*
- *Also, the HU in an ROI and the area of the ROI will be gathered*

The data will be collected from the Picture archiving and communication system (PACS) retrospectively, and measurements must be performed, also retrospectively."

No identifiable data will be stored. The data will only be used during the time the student is working on the master degree.

Planned date of conclusion is at the end of the year 2022.

The National Bioethics Committee hereby grants your research proposal it's full approval.

The National Bioethics Committee kindly requests that researchers include the given referral no. given to their project by the committee in published research papers. The National Bioethics Committee would also like to receive copies of research papers portraying research approved by the committee.

It is accentuated that all intended amendments to an already approved research protocol need to be submitted for approval by the National Bioethics Committee, Iceland.

Furthermore, the Principal Investigator is responsible for informing all institutions, which have approved access to data or samples or provided equipment or facilities, about the intended amendments to the research protocol.

Respectfully yours,
On behalf of the National Bioethics Committee,

Sunna Snædal, MD, Chairman

Copy: Hugrún Birnisdóttir, hugrunpala4@gmail.com

Appendix 6: License for data gathering at Akureyri University Hospital

SAk SJÚKRAHÚSIÐ Á AKUREYRI
AKUREYRI HOSPITAL

ÖRYGGI * SAMVINNA * FRAMSÆKNI

Hugrún Pála Birnisdóttir, geislafræðingur,
myndgreiningadeild SAk.

Akureyri 10. september 2020.

Efni: Umsókn um leyfi til aðgengis að gögnum myndgreiningadeildar vegna lokaverkefnis í meistaranámi í geislafræði.

Borist hefur bréf, dags. 10/9 2020 þar sem þú sækir um leyfi til að nota gögn myndgreiningadeildar SAk vegna lokaverkefnis í meistaranámi í geislafræði. Rannsóknin fjallar um geislaskammta í tölvusneiðmyndum og því þarf að safna gögnum úr myndageymslu (PACS) og skrá niður:

- AP og LAT þvermál sjúklings
- Geislaskammt (CTDI)
- Aldur sjúklings
- HU gildi í áhugasvæði (ROI)

Engin persónugreinanleg gögn verða notuð en áætlað er að safna gögnum frá 100 lungnarannsóknum og 100 kviðarholsrannsósknum. Með umsókninni fylgir ítarleg rannsóknaáætlun. Aðalleiðbeinandi er Ingrid Helene Hauge.

Undirritaður hefur kynnt sér ítarlega rannsóknaáætlun og gefur fyrir sitt leyti leyfi til að nota ofangreind gögn myndgreiningadeildar vegna lokaverkefnisins.

Gangi þér vel með verkefnið.

Með kveðju,

Sigurður E. Sigurðsson,
framkvæmdastjóri lækninga og handlækningasviðs,
Sjúkrahúsinu á Akureyri.

Afrit: Elvar Örn Birgisson, forstöðumaður myndgreiningadeildar SAk.

SES/JR

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Íslandsbanki Akureyri
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SWIFT (BIC) GLITISRE

Appendix 7: License for data gathering at the University Hospital of Iceland, Reykjavík

LANDSPÍTALI
HÁSKÓLASJÚKRAHÚS

Ingrid Helene Hauge, Medical Physicist
Oslo University Hospital, NO-0424

Reykjavík, September 18th, 2020 / Ref. 16

Subject: Difference between CTDIvoland size-specific dose estimates (SSDE) for abdomen-protocol and thorax-protocol for persons of different sizes for different CT-scanner

Dear Ingrid

We refer to Hugrún Pála Birnisdóttir's application to the Health Science Research Committee at Landspitali (HSRC-L), dated September 10th, 2020, where permission is requested to carry out the above-mentioned scientific study, at Landspítali - the National University Hospital of Iceland. Hugrún Pála states that you are the guarantor of the study, and that Steinunn Erla Thorlacius, head of the radiology department at Landspítali, is your co-worker and responsible for the conduct of the study at Landspitali. Hugrún Pála Birnisdóttir's has sent an application to the National Bioethics Committee (NBC) as well.

The HSRC-L agrees that the research takes place at Landspítali, and the investigation can begin when the committee receives the NBC license, which can be sent to the committee's e-mail address: vrn@landspitali.is
Requests for documents can be sent to the HSRC-L at its e-mail address; vrn@landspitali.is

Steinunn Erla Thorlacius, Chief of the Radiology Department at Landspítali, who is responsible for the conduct of the study at Landspítali, is responsible for all use of medical records at Landspítali in the study. Use of medical records shall take place within Landspitali premises and be in concordance with rules concerning scientific research and privacy at Landspítali.

If a researcher who needs to use medical records does not already have access to electronic medical records at the hospital, access request should be sent to the access manager at the hospital ("Aðgangsstjórn LSH – landspitali" <adgangur@landspitali.is>)

It is obligatory to register in the medical record a patients' participation in scientific research. This registration is the responsibility of the study guarantor. We request that you or your coworkers send to the HSRC-L, at the end of each study year, a list of ID numbers of the hospital's patients participating in the study. The National Health Science Research Committee will then ensure registration of participation in each patient's medical record. When sending the list, a reference must be made to the name of the research, name of the guarantor, and the National Bioethics Committee study number.
For further information contact the National Health Science Research Committee at the e-mail address: vrn@landspitali.is.

With regards
on behalf of the Medical Director of Landspítali - the National University Hospital of Iceland,

Torfi Magnússon MD,
Senior Medical and Science Advisor
Chairman of the Health Science Research Committee at Landspitali

Copy: Sunna Snædal Jónsdóttir, Chairman of the National Bioethics Committee (NBC)
Steinunn Erla Thorlacius, Chief of the radiology department
Jón Hilmar Friðriksson, Director of Services
Maríanna Garðarsdóttir, Director of Research Services
Magnús Gottfreðsson, Chief Physician of the Faculty of Science
Hugrún Pála Birnisdóttir, MSc Biomedical Science student