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Radiation dose and cancer risks from radiation exposure during abdominopelvic computed tomography (CT) scans: comparison of diagnostic and radiotherapy treatment planning CT scans

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In the present study, radiation doses and cancer risks resulting from abdominopelvic radiotherapy planning computed tomography (RP-CT) and abdominopelvic diagnostic CT (DG-CT) examinations are compared. Two groups of patients who underwent abdominopelvic CT scans with RP-CT (n = 50) and DG-CT (n = 50) voluntarily participated in this study. The two groups of patients had approximately similar demographic features including mass, height, body mass index, sex, and age. Radiation dose parameters included CTDIvol, dose–length product, scan length, effective tube current, and pitch factor, all taken from the CT scanner console. The ImPACT software was used to calculate the patient-specific radiation doses. The risks of cancer incidence and mortality were estimated based on the BEIR VII report of the US National Research Council. In the RP-CT group, the mean ± standard deviation of cancer incidence risk for all cancers, leukemia, and all solid cancers was 621.58 ± 214.76, 101.59 ± 27.15, and 516.60 ± 189.01 cancers per 100,000 individuals, respectively, for male patients. For female patients, the corresponding risks were 742.71 ± 292.35, 74.26 ± 20.26, and 667.03 ± 275.67 cancers per 100,000 individuals, respectively. In contrast, for DG-CT cancer incidence risks were 470.22 ± 170.07, 78.23 ± 18.22, and 390.25 ± 152.82 cancers per 100,000 individuals for male patients, while they were 638.65 ± 232.93, 62.14 ± 13.74, and 575.73 ± 221.21 cancers per 100,000 individuals for female patients. Cancer incidence and mortality risks were greater for RP-CT than for DG-CT scans. It is concluded that the various protocols of abdominopelvic CT scans, especially the RP-CT scans, should be optimized with respect to th

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Radiation dose and cancer risks from radiation exposure during abdominopelvic computed tomography (CT) scans: comparison of diagnostic and radiotherapy treatment plan scans

Saeed Bagherzadeh[1] · Nasrollah Jabbari[2] · Hamid Reza Khalkhali[3]

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Abstract

In the present study, radiation doses and cancer risks resulting from abdominopelvic radio tomography (RP-CT) and abdominopelvic diagnostic CT (DG-CT) examinations are compa who underwent abdominopelvic CT scans with RP-CT ($n=50$) and DG-CT ($n=50$) voluntar The two groups of patients had approximately similar demographic features including mass, h and age. Radiation dose parameters included $CTDI_{vol}$, dose–length product, scan length, effe factor, all taken from the CT scanner console. The ImPACT software was used to calculate t doses. The risks of cancer incidence and mortality were estimated based on the BEIR VII report Council. In the RP-CT group, the mean ± standard deviation of cancer incidence risk for all ca cancers was 621.58 ± 214.76, 101.59 ± 27.15, and 516.60 ± 189.01 cancers per 100,000 indivi patients. For female patients, the corresponding risks were 742.71 ± 292.35, 74.26 ± 20.26, a per 100,000 individuals, respectively. In contrast, for DG-CT cancer incidence risks were 47(and 390.25 ± 152.82 cancers per 100,000 individuals for male patients, while they were 638.65 575.73 ± 221.21 cancers per 100,000 individuals for female patients. Cancer incidence and mo RP-CT than for DG-CT scans. It is concluded that the various protocols of abdominopelvic CT scans, should be optimized with respect to the radiation doses associated with these scans.

Keywords Cancer risk · Radiation dose · Abdominopelvic CT scan · Cancer incidence · Cancer

Introduction

Based on results from biological and epidemiological studies, it is commonly accepted that cancer risk is increased by ionizing radiation exposure (National Research Council 2006). Approximately 48% of tion dose to the USA general diagnostic medical procedures. scans constitute the greatest s radiation exposures to the USA total radiation exposure) (NC 2018; Schauer and Linton 200 number of CT scan examinatio per year in 2006 to 85 million (Brenner and Hall 2007; Miglio

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patients from an abdominopelvic CT scan is about 10 mSv, which is typically several times greater than annual exposures from natural background (Zondervan et al. 2011). Furthermore, the use of treatment planning CT scans before radiation therapy has significantly increased (Sanderud et al. 2015). Given that approximately 50% of all patients with cancer receive radiation therapy in their treatment course (Mahmoudi et al. 2016), CT scans play a substantial role in staging and treatment planning in both radiation therapy and follow-up of patients with cancer (Yu et al. 2009).

CT scans in radiotherapy treatment planning are applied for two reasons: to allow an accurate identification of the location of tumor and surrounding organs at risk, and to provide a map of the tissue electron density which is used in a treatment planning system (TPS) for dose calculation (Davis et al. 2017). For accurate dose calculations, a correct relationship between CT numbers or Hounsfield units (HUs) and electron densities is necessary (Mahmoudi et al. 2016). There are many parameters included in a CT scan protocol; some, but not all, of these parameters influence HU values (Ebert et al. 2008; Skrzynski et al. 2010). Variation of HU values in CT images can result in inaccuracies in the radiation therapy process. Typically, HU tolerances of ± 20 HU for soft tissue and ± 50 HU for lungs and bone are acceptable, because they are associated with dose uncertainties of less than 1% in TPS (Davis et al. 2017). Unfortunately, there are only few published studies on the optimization of CT scan protocols in radiation therapy. Such protocols should be adjusted to optimize image quality and radiation exposures in TPS (Davis et al. 2017).

CT imaging provides good visualization of the target volume and neighboring critical normal tissue, and allows for three-dimensional (3D) dose calculations; thus, the dose distribution over the entire irradiated volume can be calculated. 3D images of target volumes and critical organs are essential for the complex planning required in novel radiation therapy modalities such as intensity-modulated radiation therapy (IMRT) (Dawson and Menard 2010). Therefore, in CT examinations for radiotherapy planning, high-quality images are required. However, such high-quality CT scans may expose patients to higher and, perhaps, unnecessary radiation doses as compared to diagnostic CT scans.

Currently, the potential risk of radiation-induced cancer resulting from diagnostic imaging procedures, with a

Research Council 2006). Thes
obtained from epidemiologica
Nagasaki atomic bomb survi
medical radiation exposures,
plants, and populations residing
dents had happened, such as t
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Wu et al. 2015).

Abdominopelvic CT scans
mon examinations in medical
involved ionizing radiation ca
induction in patients undergoin
of the fact that radiosensitive
during the procedure, and beca
scan lengths. Consequently, t
to CT scans should not be ign
although there is no clear pr
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The present study was con
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Methods

Investigated individuals

The present cross-sectional stu
and compare cancer incidence a
with abdominopelvic radiother
CT) and abdominopelvic diag
Two groups of patients from t
Iran) with RP-CT ($n = 50$) and
participated in the study. The
for each group was selected b
informed consent was obtained
inclusion criteria of the partici
emergency, non-pregnant, non
and being older than 32 years.
was excluded. The two group
mately matched for age, weig

and pitch setting.

CT scan protocol

All the participants underwent an abdominopelvic CT scan (DG-CT and RP-CT) utilizing a 64-slice CT scanner (Philips Brilliance CT 64-slice; Philips Healthcare, Amsterdam, The Netherlands). The scan parameters were 120 kVp, 184 mAs, mean ± standard deviation (SD) of the scan length of 564.34 ± 42.36 mm, a rotation time of 0.5 s, a pitch of 0.859:1, a 64 × 0.625 mm collimation size, and a 2.5 mm slice thickness, for the RP-CT scans, while the corresponding scan parameters were 120 kVp, 181 mAs, 404.84 ± 29.93 mm, 0.5 s, 0.798:1, 64 × 0.625 mm, and 2 mm, for the DG-CT scans.

Radiation dose

Organ doses were calculated by Monte Carlo simulation (ImPACT CT dosimetry software package, version 1.0.4; developed by the scanner evaluation center of United Kingdom National Health Service), using a standardized hermaphrodite adult-stylized phantom to model photon transport from CT (Jones and Shrimpton 1993; Shrimpton et al. 2006; Jansen and Shrimpton 2011) and National Radiological Protection Board (NRPB) Monte Carlo datasets. ImPACT CT dosimetry software involves some uncertainties in calculating effective and organ doses in body CT images (Salimi et al. 2018). However, their effects on the results of this study are negligible due to the use of nearly similar demographic characteristics for both patient groups (RP-CT and DG-CT). To perform dose calculation for each patient, radiation dose parameters such as $CTDI_{vol}$, DLP, pitch value, kVp, and mAs as recorded by the CT scanner console were used.

Based on the BEIR VII report, sensitive organs included in the cancer risk estimations were stomach, liver, colon, bladder, lung, prostate (for men), and uterus, ovarian, and breast (for women) (Huda et al. 2011). Radiation dose calculations and cancer risk estimations were performed assuming only a single CT scan per patient. Dose calculations were made in the following order:

Organ dose in the standard patient (70 kg) was calculated using Eq. 1

where $(\text{Organ dose})_{\text{ImPACT}}$ is
the ImPACT software, and (C
acquired from ImPACT.

Organ doses in a patient w
$\text{dose})_{\text{W}}$, were calculated as (Eq

$$(\text{organ dose})_{\text{W}} = (\text{organ dose})_{7}$$

where the W-factor denotes

Equation 4 can be used to c
each patient and the ImPACT
The weighting correction facto
size (70 kg) would be 1.0. For
an increase in the size of the p
in the W-factor, and vice versa

$$R(W) = 1.73 - 1.33 \times 10^{-2}\ W$$

in which R(W) represents th
weight correction factor, and W

The effective radiation dose
from Eq. 5

$$\text{Effective dose (mSv)} = \text{DLP} \times$$

where DLP (mGy.cm) was
console.

The C-factor is a correction
the effective dose by the DLP
obtained from ImPACT calcul
was mSv/mGy.cm unit

$$\text{C - factor} = \frac{E_{\text{ImPACT}}}{\text{DLP}_{\text{ImPACT}}},$$

where E_{ImPACT} represents th
the ImPACT software, and DL
from ImPACT.

Estimation of cancer risk

The risk of cancer induction
Biologic Effects of Ionizing F
(National Research Council 20
lifetime attributable risk (LAR

of exposure, 'a' is the attained age, which is calculated as e + L to 100 (L being the risk-free latent period that equals 5 years) accounting for the remaining lifetime, S(a) indicates the probability of survival until age 'a', and S(e) is the probability of survival until age 'e'.

Calculation of cancer risk can be performed for particular cancers and also for all cancers combined (Smith-Bindman et al. 2009; Hoang et al. 2015). In the present study, the cancer types considered in the calculation of cancer risk were as follows: all cancers, leukemia, and all solid cancers. The risks of cancer incidence and cancer mortality were also calculated based on the method proposed by the BEIR VII committee (National Research Council 2006). The age- and sex-specific cancer incidence and mortality risks for a specific cancer were estimated using the linear interpolation of the two closest listed ages (Tables 12D-1 and 12D-2 of the BEIR VII document) (Einstein et al. 2007; Smith-Bindman et al. 2009).

Statistical analysis

All the statistical analyses were performed using the SPSS statistical software package (SPSS Inc., Chicago, IL, USA, version 16.0). Linear polynomial regression models were used to estimate cancer incidence and mortality risks. To fit the data, standardization methods were used, which included constant variance and linearity of the dependent variable to the independent variable. In addition, student's independent *t* test was utilized to compare means of the continuous variables between the two groups. Differences were interpreted as statistically significant if the p value was < 0.05.

Results

Table 1 shows age, mass, height, and BMI for the two groups of patients.

$CTDI_{vol}$, DLP, and scan length values for RP-CT were 12.56 ± 2.81 mGy, 841.50 ± 229.02 mGy.cm, 646.27 ± 17.92 mGy.cm, and

tively. The mean values of DL

BMI showed that DLP and CT

ing BMI in both groups (Fig. 1

The effective radiation dose

and 12.08 ± 3.51 mSv for males

compared to 10.73 ± 1.53 and 1

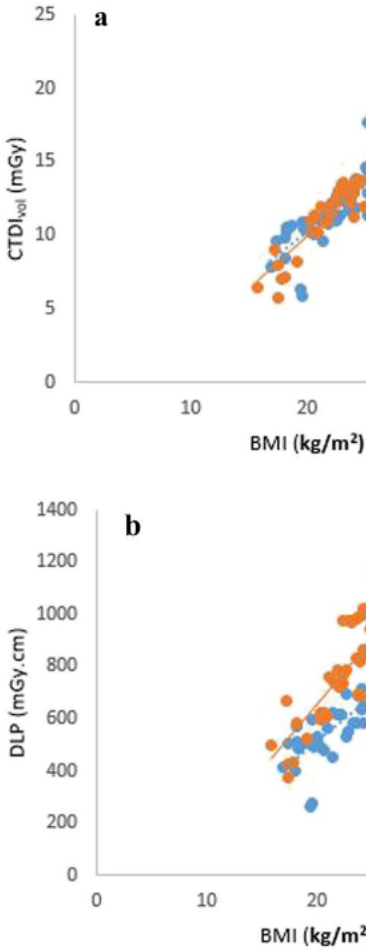

Fig. 1 Scatter plots of volume-co ($CTDI_{vol}$) versus body mass index (uct (DLP) versus BMI (**b**), in abdor planning computed tomography (R CT) scans; dotted and solid lines ind

Table 1 Demographic and physical characteristics of the patients included in the present study

Mean ± SD			
	Men		Wo
	RP-CT	DG-CT	RP-

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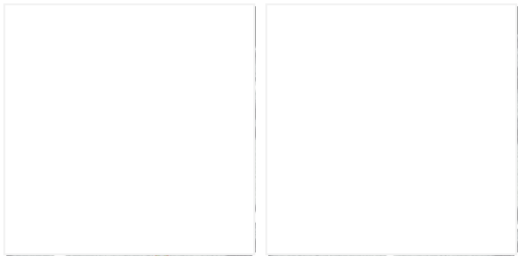

Impact of Iterative Reconstruction Algorithms on Image Quality and Radiation Dose in Computed Tomography Scan of Patients with Malignant Pancreatic Lesions

New Article Full-text available

January 2022 · Journal of Medical Signals & Sensors

Ali Chaparian · Mohamadhosein Asemanrafat · Mehrzad Lotfi · Alireza Rasekhi

Background: The objective of this study was to investigate the influence of iterative reconstruction (IR) algorithm on radiation dose and image quality of computed tomography (CT) scans of patients with malignant pancreatic lesions by designing a new protocol. Methods: The pancreas CT was performed …

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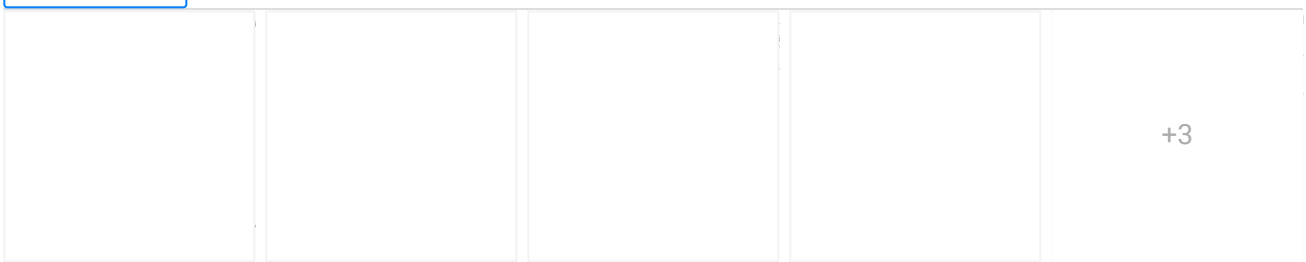

Estimation of Lifetime Attributable Risks (LARs) Associated with Abdominopelvic Radiotherapy Treatment Planning Computed Tomography (CT) Simulations

Article Full-text available

March 2018 · International Journal of Radiation Biology

Predicting Cancer Risks from Dental Computed Tomography

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October 2014 · Journal of Dental Research

Tai-Hsien Wu · Wei-Chan Lin · Wun-Ke Chen · [...] · Jeng-Jong Hwang

Dental computed tomography (CT) has become a common tool when carrying out dental implants, yet there is little information available on its associated cancer risk. The objective of this study was to estimate the lifetime-attributable risk (LAR) of cancer incidence that is associated with the radiation…

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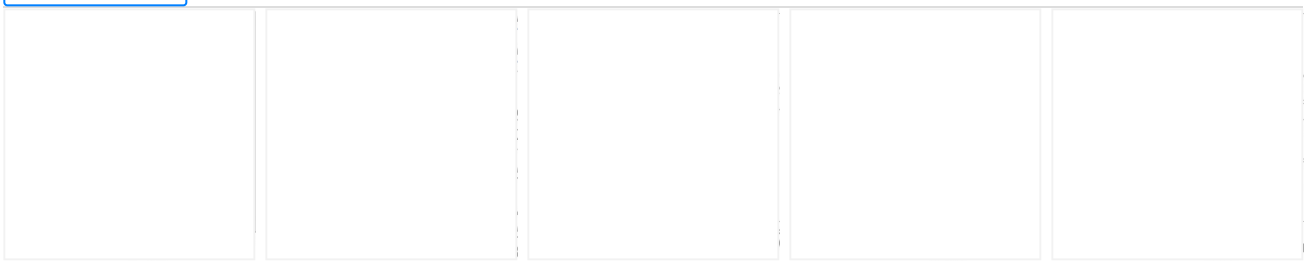

Estimating cancer induction risk from abdominopelvic scanning with 6- and 16-slice computed tomography

Article Full-text available

December 2016 · International Journal of Radiation Biology

Parinaz Mehnati · Ayoub Amirnia · Nasrollah Jabbari

Purpose: The biological effects of ionizing radiation (BEIRVII) report estimates that the risk of getting cancer from radiation is increased by about a third from current regulation risk levels. The propose of this study was to estimate cancer induction risk from abdominopelvic computed tomography (CT)…

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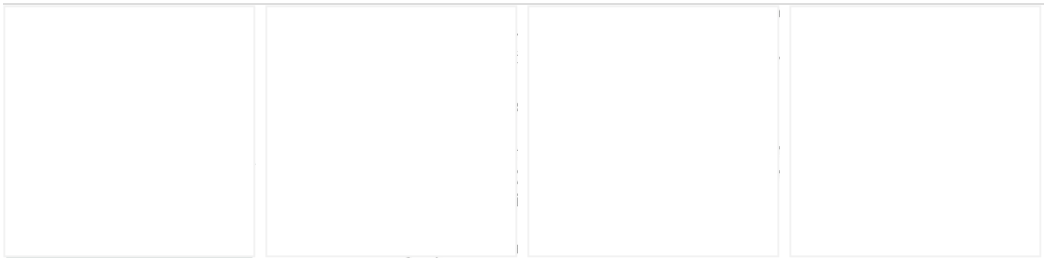

Assessment of the variation in CT scanner performance (image quality and Hounsfield units) with scan parameters, for image optimisation in radiotherapy treatment planning

similar investigations in the literature may be a contributing factor in the apparent reluctance to optimi…