Cumulative Effective Dose Caused by Diagnostic Imaging and its Associated Risk for Cancer Development in Trauma Patients Referred to the Emergency Department

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Background: The current study aimed to determine the cumulative effective dose caused by diagnostic imaging and its associated risk for cancer development in trauma patients referred to an emergency department. Methods: This study was carried out retrospectively in an emergency department (Kashan, Iran) from April 2015 to October 2015. Then, the types of diagnostic radiologic studies performed on adult trauma patients in their first 24 h upon presentation were recorded. Finally, the cumulative effective dose of trauma patients and its associated risk for cancer development were obtained. Results: In total, the patients received 3323 radiologic examinations including 2169 radiographs and 1154 computed tomography (CT)-scans. The most common type of plain radiographic and CT-scan examinations included anterior posterior and posterior anterior chest as well as head, respectively. The mean cumulative effective dose received by trauma patients referred to the emergency department was 2.47 ± 4.29 mSv. Most of the effective dose was from CT-scan examinations (90.65% of total cumulative effective dose; 2181.91 mSv). The majority of patients (83.40%) received between 0.00 and 5.00 mSv cumulative effective dose. Moreover, the cancer risk per average cumulative effective dose received by trauma patients was 1.01 × 10⁻⁴. Conclusions: In current study, the mean cumulative effective dose per each trauma patient (2.47 mSv) was relatively less than that of the other evaluated studies. It was also found that although the number of CT-scans was relatively few compared to plain radiographs, most of the cumulative effective dose of patients resulted from CT-scans; hence, using unnecessary CT-scan examinations should be avoided.

Key words: Cancer risk, computed tomography, cumulative effective dose, emergency department, radiology, trauma

INTRODUCTION

Diagnostic radiology studies are widely performed in emergency departments. They provide accurate and rapid diagnosis for emergency physicians to evaluate life-threatening injuries of emergency patients. Trauma patients are highly at risk, especially for high-dose radiation exposure. Most of these patients receive multiple radiographs and computed tomography (CT) scans during their hospitalization.

The ionizing radiation generated by radiologic studies (radiographs and CT scans) has been associated with certain risks. Overall, these associated risks can be classified into two radiation effects which can be measured in dose values: (1) radiation dose for acute exposure effect and (2) effective dose for chronic exposure effect. It is notable that due to the lack of producing harmful level of radiation dose (usually <10 mGy), the radiologic studies are not accompanied by acute exposure effect. Nevertheless, the chronic exposure effect or stochastic effects, which include hereditary and carcinogenesis effects,

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are the most concerning effects of radiologic studies. Despite these risks, using radiologic imaging has been growing over the past decades, especially in emergency departments. One of the reasons is that the radiologic imaging is greatly beneficial for emergency physicians in time-limited settings. In addition, compared to other presently available modalities, the radiologic imaging is highly accurate, noninvasive, and has a very high sensitivity to diagnose blunt injuries.

The international commission on radiation protection (ICRP) Publication No. 103 has suggested an assessment of the radiation risks caused by diagnostic imaging using received doses to tissues at risk. Moreover, effective dose can be applied for comparing dose values from similar diagnostic procedures and technologies in various medical clinics and countries. In addition, if reference patient groups are same by sex and age, this quantity can be used to compare various technologies for similar examinations. Effective dose is defined as sum of the tissue dose equivalents and it is a single quantity representing the overall radiation effect on the whole organism. Cumulative effective dose is also calculated to determine the biological effects of absorbed dose. This quantity is defined as sum of the effective dose values of all radiologic studies. Both of these quantities are measured by rem and Sievert.

Because of the severity of injuries, trauma patients undergo multiple diagnostic imaging, even during their initial 24 h of evaluation after their presence at emergency departments. This issue has raised concerns among radiologists and emergency physicians believing that these patients may have been over-radiated which increases their risks of developing malignancy along with ionizing radiation. On the other hand, the injured patients are usually at a young age and hence, they are more sensitive to radiation effect. Hence, the optimization of scan parameters should be powerfully emphasized according to the as low as reasonably achievable principle in trauma radiology, particularly in trauma CT scans.

While several studies have been previously carried out in other countries to investigate the effective dose from the radiologic studies in trauma patients referred to emergency departments, to the best of our knowledge, there is no similar study conducted in Iran. Therefore, the current study aimed to determine the amounts of cumulative effective dose caused by diagnostic imaging in trauma patients referred to an emergency department in Iran. The present study also aimed to find out that which specific types of diagnostic imaging procedures exposed trauma patients with the highest effective radiation dose. In addition, the cumulative effective dose of diagnostic imaging obtained from the current study was compared with that of the other studies. Finally, the cancer risk following diagnostic imaging in trauma patients was estimated.

METHODS

Study period and population

Using the hospital information system, all radiographic studies of trauma patients referred to the emergency department of Shahid Beheshti hospital with Level III trauma center (Kashan, Iran) were retrospectively reviewed from April 2015 to October 2015. Types of diagnostic radiologic examinations performed on adult trauma patients (>18 years) in their first 24 h upon presentation were also recorded. Furthermore, those patients who were transferred from other institutions were excluded from the study. Demographic data including sex, age, and number and type of diagnostic radiologic examinations of the patients were also assessed. In terms of age, the patients were classified into three groups: young (>18–35 years), middle aged (>35–50 years), and old (>50 years).

During the 6-month study period, 975 adult patients (685 male and 290 female patients) met the study inclusion criteria and incorporated in this study with an age ranging from 18 to 98 years (mean age of 43.46 ± 20.33 years). Number of patients in young, middle aged, and old age groups was 465, 202, and 308, respectively.

Radiographic studies

In the current research, the radiographic studies included plain radiographs and CT scans. The plain radiographic examinations incorporated in this study were anterior posterior (AP) and lateral (Lat) lumbar spine, AP pelvis, AP, posterior anterior (PA), and Lat chest, AP, PA, and Lat skull, and AP abdomen. Furthermore, CT scan examinations included head, abdomen, pelvic, and chest. In total, there were 3323 radiologic examinations, of which 2169 plain radiographs and 1154 CT-scans were recorded for all groups. Figure 1a and b shows the frequency of plain radiographic and CT-scan examinations for each radiologic study, respectively.

It is noteworthy that the plain radiographic equipment applied in this research was all analog, the film screen combination speed was 400, and the total filtration ranged from 2.00 to 3.5 mm Al. Furthermore, CT scan examinations were performed based on standard protocols using single-slice CT scanner (Toshiba, Japan). Mean values of kVp and mA for plain radiographic were 73.5 ± 6.0 and 24.8 ± 7.9, respectively. However, values of kVp and mA range for CT scan examinations were 120 and 120–200, respectively.

Estimation of the effective dose and cumulative effective dose

For each type of diagnostic imaging, an effective dose was estimated from data presented in our previous studies. The
effective doses of plain radiographs were extracted from and the calculation method of effective doses is explained in details in this reference. In addition, the effective doses of CT-scan examinations were obtained by multiplying dose-length product (DLP) by conversion coefficients presented which DLP values for each CT-scan examination were extracted from. There are several studies which have used the estimation method of effective dose for calculating the radiation dose from radiologic studies of trauma patients. The cumulative effective dose was calculated as the sum of effective doses of all radiographic studies. Tables 1 and 2 demonstrate the effective dose related to each procedure of diagnostic imaging investigated in the current study.

Cancer risk estimation
In the current study, the cancer absolute risks following radiologic examinations were estimated on the basis of the risk model described in ICRP Publication 103. Absolute risk is defined as the probability that a person who is disease-free at a specific age will develop the disease at a later time following exposure to a risk factor, e.g., the probability of cancer induction following exposure to radiation. To obtain this cancer risk, average cumulative effective dose resulting from radiologic examinations was multiplied by the risk coefficient (0.041 Sv⁻¹).

RESULTS
The average cumulative effective dose received by each trauma patient was 2.47 ± 4.29 mSv (ranged from 0.02 to 25.61 mSv). Most of the effective dose was from CT-scan examinations (90.65% of total cumulative effective dose), while plain radiographic examinations contributed to a smaller proportion of it (9.35% of total cumulative effective dose). In addition, the cumulative effective doses related to each radiologic study were obtained as well [Figure 2a and b].

In total, cumulative effective dose of patients ranged from 0.00 to 25.00 mSv. Figure 3 shows the distribution of these doses received by trauma patients per visit.

Furthermore, Table 3 presents the cumulative effective dose of patients from diagnostic studies for different age groups.

Number of radiologic studies (by age groups and gender) and associated cumulative effective doses are listed in Tables 4-7.

Patient cancer risk per average total cumulative effective dose (plain radiographic and CT-scan examinations) received by trauma patients was 1.01 × 10⁻⁴.

DISCUSSION
The present study was prospected to determine the cumulative effective dose of diagnostic imaging in trauma patients referred to an emergency department in Kashan, Iran. Furthermore, cumulative effective doses related to each of the diagnostic imaging modality, age groups, and gender were obtained as well. Finally, cumulative effective dose caused by diagnostic imaging in trauma patients was used to estimate the cancer risk.

According to the demographic data, most of the trauma patients referred to the emergency department were
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males (70.26%; in terms of gender) and young (47.69%; in terms of age group).

As seen in Figure 1, the most common type of examinations for plain radiographic and CT-scans included AP and PA chest (40.57%) and head (67.42%), respectively. Furthermore, the Lat, AP, and PA skull plain radiographic (0.97%) and chest CT-scan (7.54%) were less common than others.

Based on the results of the current study [Figure 1a], most of the plain radiographic examinations included AP and PA chest, while [Figure 2a] the most cumulative effective dose resulted from AP pelvis (45.91%); because AP pelvis effective dose is higher than the AP and PA chest effective dose (0.19 mSv vs. 0.03 mSv). In addition, most of the CT-scan examinations were taken from the head; however, the highest cumulative effective dose of these examinations was related to abdomen (32.88%). The lowest cumulative effective doses were related to Lat skull plain radiographic (0.004%) and head CT-scan (15.19%), because these radiologic images were the least requested by physicians.

Table 2: The mean computed tomography dose index, dose-length product and effective dose of each computed tomography-scan procedure

| Types of CT-scan procedures | CTDI (mGy)  | DLP (mGy.cm) | Conversion factor (mSv/mGy/cm) | Effective dose (mSv) |
|-----------------------------|-------------|--------------|--------------------------------|----------------------|
| Chest                       | 15.47±0.82  | 307.33±18.37 | 0.021                          | 6.45                 |
| Pelvis                      | 10.08±1.45  | 189.37±31.85 | 0.017                          | 3.22                 |
| Abdomen                     | 13.95±0.45  | 346.07±16.98 | 0.017                          | 5.88                 |
| Head                        | 34.11±2.77  | 362.67±1.68  | 0.0013                         | 0.47                 |

CT=Computed tomography; DLP=Dose-length product; CTDI=CT dose index

Table 3: Average cumulative effective dose caused by diagnostic studies in different age groups

| Age groups | Number of patients (male:female) | Cumulative effective dose (mSv) | Average cumulative effective dose (mSv) |
|------------|----------------------------------|---------------------------------|----------------------------------------|
|            | Male | Female | Total | Male | Female | Total | Total | |
| Young      | 465  | 367:98 | 918.69| 216.15| 1134.84 | | 2.44±4.49 |
| Middle-aged| 202  | 144:58 | 441.38| 191.92| 633.30  | | 3.13±4.69 |
| Old        | 308  | 174:134| 395.76| 243.16| 638.92  | | 2.07±3.62 |

Figure 2: Cumulative effective doses of different plain radiographic (a) and computed tomography-scan (b) examinations

Figure 3: Distribution of cumulative effective doses received by trauma patients per visit
According to the results shown in Figure 3 and 83.40% of the patients received between 0.00 and 5.00 mSv cumulative effective dose from diagnostic imaging, while 0.50% of the patients received between 20.1 and 25 mSv. A small percentage of the patients (16.10%) received between 5.01 and 20 mSv of cumulative effective doses.

On average, the cumulative effective dose of patients from diagnostic studies was obtained 2.44 ± 4.49, 3.13 ± 4.69, and 2.07 ± 3.62 mSv for young, middle-aged, and old age groups, respectively [Table 3]. Among different age groups, the highest cumulative effective dose was received by the young group.

In terms of age groups, most of the plain radiographic and CT-scan examinations belonged to young population, which it consequently resulted in the most cumulative effective dose in this age group [Tables 4 and 5]. Considering the three age groups, the most plain radiographic examinations and cumulative effective dose were related to AP and PA chest and AP pelvis respectively [Table 4]. Furthermore, the most CT-scan examinations and cumulative effective dose (young and middle-aged groups) were related to head and abdomen, respectively [Table 5].

With regard to the gender, most of the plain radiographic and CT-scan examinations belonged to the male group, which consequently led to the most cumulative effective dose in this gender [Tables 6 and 7]. In both male and female groups, the most plain radiographic examinations and cumulative effective dose were related to AP and PA chest and AP pelvis examinations, respectively [Table 6]. Furthermore, the most CT-scan examinations and cumulative effective dose were related to head and abdomen, respectively [Table 7].

In a study by Tien et al., the radiation doses received by trauma patients from diagnostic imaging were measured. In that study, dosimetry of 172 patients was carried out during CT scans, plain film radiography, interventional radiography, fluoroscopy, and nuclear medicine scans. Their findings showed that 86% of the estimated cumulative effective dose was from CT-scan examinations; this amount was less than what is reported in the current study in which CT-scan examinations...
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Contribute to 90.65% of total cumulative effective dose. In that study, the mean cumulative effective dose received by patients was 22.7 mSv, while it was 2.47 mSv in the current study. One of the reasons for this difference lies in having different radiologic studies in that study compared to our study. In another study, Tjiang and Richardson determined the cumulative effective dose of adult trauma patients referred to an emergency department during the initial 24 h of their care. In this study, the cumulative effective dose of 118 patients was evaluated during a year. Their results demonstrated that average cumulative effective dose of patients from diagnostic studies was 11.3 mSv which it was more than what was estimated in the present study. In addition, their results indicated that most of the cumulative effective dose was from CT-scan examinations as it was also shown in the current study; indicating that their contribution in that study was higher than our study (94% vs. 90.65%). Other results showed that most of the trauma patients referred to the emergency department received 0.00 mSv to 5.00 mSv cumulative effective dose. These findings were in consistent with our results; however, their contribution in this study was less than our study (42.4% vs. 83.40%). In a cross-sectional study, You et al. analyzed the radiation exposure of conventional radiographs and CT scans received by the injured patients referred to an emergency department. 11676 patients were incorporated in this study. The cumulative effective dose of CT-scan examinations consisted 87.1% of total cumulative effective dose which this amount was less than that of the current study. Additionally, the average cumulative effective dose was 2.6 mSv, and it was similar to the results of the current study. Most of the patients (87%) received 0.00–3.00 mSv effective dose. These findings were almost similar to our results in which 83.40% of the patients received 0.00–5 mSv cumulative effective dose. There are several other studies which showed a high cumulative effective dose compared to our study. In a study by Winslow et al., the amount of ionizing radiation of 86 adult blunt trauma patients during the initial 24 h of their care was evaluated and the median cumulative effective dose of ionizing radiation was 40.2 mSv. In another study by Salerno et al., the cumulative effective dose of 249 young adult patients was assessed. Their results revealed a mean cumulative effective dose of 27 mSv (ranged from 3 to 297 mSv). Moreover, Sharma et al. assessed the cumulative effective dose of 177 patients admitted to a trauma service center. The mean cumulative effective dose of the patients was 11.76 mSv in the first 24 h after arrival. In addition, Kim et al. investigated the cumulative effective dose caused by radiologic studies in 46 trauma patients. Their findings showed a mean cumulative effective dose of 106 mSv (ranging from 11 to 289 mSv).

The mean cumulative effective dose obtained from the current study and other studies as well as the several properties of these studies are tabulated in Table 8.

There are some studies which have evaluated the cancer risk from diagnostic imaging. Alkhoryayef et al. measured the patient radiation dose during a CT angiography procedure and estimated the patient radiation biological risk. They revealed that the overall patient risk per CT angiography procedure ranged between 15 and 36 malignancy risks per 1,000,000 procedures. Furthermore, their findings showed that the patient cancer risk was high during abdomen and neck procedures. In another study, Smith-Bindman et al. stated that the estimated number of CT examinations leading to the development of a cancer varies widely depending on the particular type of CT-scan and the patient’s sex and age. For example, they reported that an estimated 1 in 600 males who underwent a coronary angiography CT scan at age 40 would develop cancer from that CT procedure (1 in 270 females), compared with an estimated 1 in 11,080 males who had routine head CT at the same age (1 in 8100 females). In addition, for 20-year-old individuals, the cancer risks were about doubled, and for 60-year-old individuals, the cancer risks were about 50% lower. De Gonzalez and Darby stated that in the UK about 0.6% of cumulative cancer risk for those aged 75 years could be due to diagnostic X-rays, as this contribution was

| Author and year | Country | Type of radiologic study | Mean cumulative effective dose (mSv) |
|-----------------|---------|--------------------------|-------------------------------------|
| Tien et al., 20079 | Canada | Plain radiography, interventional radiography, fluoroscopy, and nuclear medicine scans, and CT scans | 22.7 |
| Tjiang and Richardson, 2011 | Australia | Plain radiography and CT scans | 11.3 |
| You et al., 2013 | South Korea | Plain radiography and CT scans | 2.6 |
| Winslow et al., 2008 | The USA | Plain radiography and CT scans | 40.2 |
| Salerno et al., 2016 | Italy | CT scans | 27 |
| Sharma et al., 2011 | The USA | Plain radiography and CT scans | 11.76 |
| Kim et al., 2004 | The USA | Plain radiography, CT scans, fluoroscopic study, and nuclear medicine | 106 |
| Current study | Iran | Plain radiography and CT scans | 2.47 |

CT=Computed tomography
equivalent to approximately 700 cases of cancer per year. Furthermore, they estimated that the attributable cancer risk ranged from 0.6% to 1.8% in 13 other developed countries.

The results of the current research demonstrated that the mean cumulative effective dose received by trauma patients was 2.47 mSv which this amount of ionizing radiation is almost near the normal background effective dose received by an individual in a year (3.00 mSv). On the other hand, using the linear nonthreshold model – an accepted method for estimation of the risk of low level ionizing radiation – it can be pointed out that there is no safe level of radiation exposure; hence, any dose can lead to cancer or genetic mutations. Therefore, clinicians should try to minimize the received radiation dose by the patients. The first and the most effective approach to diminish radiation exposure is to avoid implementation of unnecessary examinations (especially CT-scans). Second approach is to reduce the repeated imaging studies. Third, if technically possible, dose reduction techniques like automatic modulation of tube current/voltage, and image noise reduction through using iterative reconstruction algorithms should be used. Fourth, using alternative imaging modalities such as magnetic resonance imaging or ultrasonography can diminish the radiation exposure. Finally, fifth approach is that clinical evaluation criteria rather than a radiologic study can present a diagnosis plan or alternative treatment.

**Limitations**

There are several limitations in the current study. First, this study was carried out retrospectively which it indicates the limitations related to missing data as well as the possibility of errors in data collection. Second, the current study includes only the findings from a single emergency department; hence, it does not take various practice patterns at different centers. Third, the data presented in the current study might underestimate the mean cumulative effective dose received by trauma patients because other imaging modalities (like fluoroscopy and angiography which have higher exposure of effective dose) were not included in this study (because the trauma center was level III). Fourth, this study was conducted on adult trauma patients, while radiation exposure is a more important health issue for children because they are more radiosensitive and have more years to present stochastic effects.

**CONCLUSIONS**

The findings showed that the mean cumulative effective dose received by trauma patients referred to an emergency department was 2.47 ± 4.29 mSv. Although this amount of dose was relatively low, clinicians should keep radiation doses from diagnostic imaging as low as reasonable. Number of CT-scans was relatively few compared to plain radiographs, but most of the cumulative effective dose of patients resulted from CT-scans. Hence, using unnecessary CT-scan examinations should be avoided. Furthermore, the results demonstrated that the most cumulative effective doses for plain radiography and CT-scan examinations were related to AP pelvis and abdomen, respectively. Finally, the patient cancer risk per average total cumulative effective dose received by trauma patients was $1.01 \times 10^{-4}$.

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**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed. The study is approved by Institutional Review Board of Kashan University of Medical Sciences. The approval number is IR.KAUUMS.REC.1398.042.

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**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Tjiang HH, Richardson D. Radiation exposure from diagnostic imaging in trauma patients presenting to emergency department. MSJA 2011;3:4-11.
2. Kim PK, Gracias VH, Maidment AD, O’shea M, Reilly PM, Schwab CW. Cumulative radiation dose caused by radiologic studies in critically ill trauma patients. J Trauma Acute Care Surg 2004;57:510-4.
3. Berrington de González A, Darby S. Risk of cancer from diagnostic X-rays: Estimates for the UK and 14 other countries. Lancet 2004;363:345-51.
4. Bailitz J, Starr F, Beecroft M, Bankoff J, Roberts R, Bokhari F, et al. CT should replace three-view radiographs as the initial screening test in patients at high, moderate, and low risk for blunt cervical spine injury: A prospective comparison. J Trauma Acute Care Surg 2009;66:1605-9.
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5. Holmes JF, Akkinepalli R. Computed tomography versus plain radiography to screen for cervical spine injury: A meta-analysis. J Trauma Acute Care Surg 2005;58:902-5.

6. International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann ICRP; 2007. p. 21.

7. Salottolo K, Bar-Or R, Fleishman M, Maruyama G, Slone DS, Mains CW, et al. Current utilization and radiation dose from computed tomography in patients with trauma. Crit Care Med 2009;37:1336-40.

8. Kim PK, Zhu X, Houseknecht E, Nickolaus D, Mahboubi S, Nance ML. Effective radiation dose from radiologic studies in pediatric trauma patients. World J Surg 2005;29:1557-62.

9. Tien HC, Tremblay LN, Rizoli SB, Gelberg J, Spencer F, Caldwell C, et al. Radiation exposure from diagnostic imaging in severely injured trauma patients. J Trauma Acute Care Surg 2007;62:151-6.

10. Kortesniemi M, Kiljunen T, Kangasmäki A. Radiation exposure in body computed tomography examinations of trauma patients. Phys Med Biol 2006;51:3269-82.

11. Winslow JE, Hinshaw JW, Hughes MJ, Williams RC, Bozeman WP. Quantitative assessment of diagnostic radiation doses in adult blunt trauma patients. Ann Emerg Med 2008;52:93-7.

12. You JS, Lee HJ, Chung YE, Lee HS, Kim MJ, Chung SP, et al. Diagnostic radiation exposure of injury patients in the emergency department: A cross-sectional large scaled study. PLoS One 2013;8:e84870.

13. Salerno S, Marrale M, Geraci C, Caruso G, Lo Re G, Lo Casto A, et al. Cumulative doses analysis in young trauma patients: A single-centre experience. Radiol Med 2016;121:144-52.

14. Sharma OP, Oswanski MF, Sidhu R, Krugh K, Culler AS, Spangler M, et al. Analysis of radiation exposure in trauma patients at a level I trauma center. J Emerg Med 2011;41:640-8.

15. Aliashgarzadeh A, Mihandoost E, Mohseni M. A survey of computed tomography dose index and dose length product level in usual computed tomography protocol. J Cancer Res Ther 2018;14:549-52.

16. Aliashgarzadeh A, Mihandoost E, Mosumbeigi M, Salimian M, Mohseni M. Measurement of entrance skin dose and calculation of effective dose for common diagnostic x-ray examinations in Kashan, Iran. Glob J Health Sci 2015;7:202-7.

17. Christner JA, Kofler JM, McCollough CH. Estimating effective dose for CT using dose-length product compared with using organ doses: Consequences of adopting International Commission on Radiological Protection publication 103 or dual-energy scanning. AJR Am J Roentgenol 2010;194:881-9.

18. Mullenders L, Atkinson M, Paretzke H, Sabatier L, Bouffler S. Assessing cancer risks of low-dose radiation. Nat Rev Cancer 2009;9:596-604.

19. Moloney F, Fama D, Twomey M, O’Leary R, Houlihane C, Murphy KP, et al. Cumulative radiation exposure from diagnostic imaging in intensive care unit patients. World J Radiol 2016;8:419-27.

20. Alkhorayef M, Babikir E, Alrashoud A, Al-Mohammed H, Sulaiman A. Patient radiation biological risk in computed tomography angiography procedure. Saudi J Biol Sci 2017;24:235-40.

21. Wall BF, Haylock R, Jansen JT, Hillier MC, Hart D, Shrimpton DC. Radiation Risks From Medical X-Ray Examinations As A Function of the Age and Sex of the Patient. Chilton: HPA Centre for Radiation, Chemical and Environmental Hazards; 2011. p. 1-66.

22. Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med 2009;169:2078-86.

23. Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: The impact of 2007 International Commission on Radiological protection recommendations regarding dose calculation. J Am Dent Assoc 2008;139:1237-43.

24. Einstein AJ, Henzlova MJ, Rajagopalan S. Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography. JAMA 2007;298:317-23.

25. Council NR. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. Washington: National Academies Press; 2006.