A Review Study on Patient's Radiation Dose from Diagnostic Radiography

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Abstract: ***Medical x-ray exposures have the largest man made source of population exposure to ionizing radiation in different countries. Recent developments in medical imaging have led to rapid increases in a number of high dose x-ray examinations performed with significant consequences for individual patient doses and for collective dose to the population as a whole. It is therefore important in each country to make regular assessments of the magnitude of these large doses. Numerous research and techniques have been developed worldwide to measure these doses by using different tools for calculating and evaluation of doses. In this study we aimed to review the previous study which has been done in this topic.***

Keywords: radiation, dose, diagnostic, radiography.

1. Introduction

The danger and risks associated with X-rays have been extensively researched during the last century, and it is apparent that governmental supervision of X-rays usage is necessary. In 1928, the forerunner of the independent advisory body International Commission on Radiological Protection (ICRP) was founded, with the National Council on Radiation Protection and Measurements (NCRP), a U.S. advisory body, being founded the year after [1]. Since then, the ICRP have published guidelines relating to radiation protection, and the European countries use these as basis for their own national guidelines. Assessment and optimization of radiation doses received by patients are some of the most important tasks for radiation protection of patients in diagnostic radiology in medicine. The patient dose is dependent on operational parameters such as kV, mAs, body orientation (PA, AP etc.), focal-to-skin distance (FSD), field size and filtration. Therefore, the growing application of X-rays in medicine and the increasing hazards of radiation medical exposure have led to comprehensive efforts of different international committees and organizations involved in radiation protection fields for issuing reference dose values as a guide to the levels of radiation protection of patients undergoing X-ray examinations [2].

Recently, numerous research and techniques have been developed for measure and evaluate the patient doses from different diagnostic radiologic examinations, using different tools to measure the effective doses. The purpose of this review study was to enumerate in a summarized way the patient doses for conventional, computed tomography and fluoroscopic procedures and the tools used for measurements. Such review has been gathered from electronic databases of the patient who carried out relevant diagnostic procedure.

2. Literature Review

You-hyun et al, in [3] have estimated the patient dose for radiographic examinations in Korea including gastrointestinal studies, computed tomography and mammography. The survey data from 161 hospitals and the dose data from 32 hospitals were analyzed. The third quartile entrance surface dose, dose area product (DAP), weighted CT dose index (CTDIw) and mean glandular dose (MGD) were reported. All the estimated doses were less than the dose stated by International Atomic Energy Agency (IAEA) reference levels for radiographic examinations, as stated by NRPB – protocol (5). However DAPs for the fluoroscopic examinations was higher than the IAEA reference levels i.e. the SD for barium meal was 34.87 Gy, while the IAEA recommendation was 25 Gy/cm2, and the barium enema dose was 73.89 Gy, while he IAEA recommendation was 60 Gy.cm2). In addition, the CTDIw and MGD were lower than the IAEA. Eric et al, [4] estimated the patient dose for skull radiographic examinations in ten hospitals in Ghana. Dose measurements were calculated for 365 patients [164 (44.9%) male, 201 (55.1%) female, ages, 38.42 years ± 9.90; range 18– 73]. The entrance surface dose (ESD) was determined by an indirect method, using the patient's anatomical data and exposure parameters utilized for the specific examination. The Quality Assurance Dose Database software (QADDs) (NRPB; 1992) developed by Integrated Radiological Services Ltd. in Liverpool, UK was used to generate the ESD values. They identified variations in the technique factors used compared with the recommendations in the European Commission quality criteria. They found that: (60%) and 70% of the hospitals exceeded the DRL values for UK-2005 for posteroanterior and lateral projections respectively. And the variations in the data recorded demonstrate the importance of quality assurance and standardization of protocols to ensure satisfactory standards and optimized radiation dose to patients and staff.

David et al, [5] calculated the effective dose from diagnostic computed tomography (CT) scans in Saskatchewan, Canada, and compared with other reported dose levels. Data from CT scans were collected from 12 scanners in 7 cities across Saskatchewan. The patient age, scan type, and selected technique parameters including the dose length product and the volume computed tomography dose index were collected for a 2-week period. The information then used to calculate the effective doses during CT examinations. Data from 2,061 clinically indicated CT examinations were collected, and of them 1,690 were eligible for analysis. Every examination during a 2-week period was recorded without selection.

The average provincial estimated patient dose was as follows: head, 2.7 mSv (638 scans; standard deviation [SD], +/-1.6); chest, 11.3 mSv (376 scans; SD, +/-8.9); abdomen-pelvis, 15.5 mSv (578 scans; SD, +/-10.0); abdomen, 11.7 mSv (80 scans; SD, +/-11.48), and pelvis, 8.6 mSv (18 scans; SD, +/-6.04). Significant variation in dose between the CT scanners was observed (P = 0.049 for head, P = 0.001 for chest, and P = 0.034 for abdomen-pelvis). Overall, the estimated dose from diagnostic CT examinations was similar to other previously published Canadian data from British Columbia. This dose varied slightly from some other published standards, including being higher than those found in a review conducted in the United Kingdom in 2003.

Olgar et al, [6] they measured patient and staff doses simultaneously for some complex x-ray examinations. Measurements of dose-area product (DAP) and entrance skin dose (ESD) were carried out in a sample of 107 adult patients who underwent different x-ray examinations such as double contrast barium enema (DCBE), single contrast barium enema (SCBE), barium swallow, endoscopic retrograde cholangio-pancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC), and various orthopaedic surgical procedures. Dose measurements were made separately for each projection, and DAP, thermoluminescent dosimetry (TLD), film dosimetry and tube output measurement techniques were used. Staff doses were measured simultaneously with patient doses for these examinations, with the exception of barium procedures. The measured mean DAP values were found to be 8.33, 90.24, 79.96 Gy cm (2) for barium swallow, SCBE and DCBE procedures with the fluoroscopy times of 3.1, 4.43 and 5.86 min, respectively. The calculated mean DAP was 26.33 Gy cm (2) for diagnostic and 89.76 Gy cm (2) therapeutic ERCP examinations with the average fluoroscopy times of 1.9 and 5.06 min respectively. Similarly, the calculated mean DAP was 97.53 Gy cm (2) with a corresponding fluoroscopy time of 6.1 min for PTC studies. The calculated mean entrance skin dose (ESD) was 172 mGy for the orthopedic surgical studies. Maximum skin doses were measured as 324, 891, 1218, 750, 819 and 1397 mGy for barium swallow, SCBE, DCBE, ERCP, PTC and orthopedic surgical procedures, respectively. The high number of radiographs taken during barium enema examinations, and the high x-ray outputs of the fluoroscopic units used in ERCP, were the main reasons for high doses, and some corrective actions were immediately taken.

Milatović et al, [7] they estimated the first time patient dose levels in conventional diagnostic radiology in Montenegro. Measurements of patient dose in terms of entrance surface air kerma (ESAK) and kerma-area product (KAP) were performed on at least 10 patients for each examination type, in each of five randomly selected health institutions in Montenegro, so that a total of 872 patients for 16 different examination categories were included in the survey (817 patients for 1049 radiographies and 55 fluoroscopy patients). Exposure settings and individual data were recorded for each patient. Mean, median and third quartile values ESAK of patient doses are reported. The estimated mean ESAK values obtained are as follows: 4.7 mGy for pelvis anteroposterior (AP), 4.5 mGy for lumbar spine AP, 7.8 mGy for lumbar spine lateral (LAT), 3.1 mGy for thoracic spine AP and 4.3 mGy for thoracic spine LAT. When compared with the European diagnostic reference values, the mean ESAK for all studied examination types are found to be below the reference levels, except in chest radiography. Mean ESAK values for chest radiography are 0.9 mGy for posteroanterior (PA) projection and 2.0 mGy for LAT. The results exhibit a wide range of variation. For fluoroscopy examinations, the total KAP was measured. The mean KAP value per procedure for barium meal is found to be 22 Gy cm (2), 41 Gy cm (2) for barium enema and 19 Gy cm (2) for intravenous urography. Broad dose ranges for the same types of examinations indicate the necessity of applying practice optimization in diagnostic radiology and establishment of national diagnostic reference levels.

Hirofuji et al, [8] they assessed the patient doses for examinations of the lower digestive tract (barium enemas and CT colonography) in Japan. These doses were evaluated from in-phantom dose measurements using a dosimeter-implanted anthropomorphic phantom and from the knowledge of procedures of these examinations. For barium enemas, the doses, which were the sums of doses for various projections in the procedure, were separately derived for fluoroscopy and for analogue and digital radiography. For CT colonography, the doses were evaluated for the prone and the supine positions, each including the doses by scout imaging, and a single abdominal scan for routine and low-dose set-ups. For barium enemas, maximum local skin doses were less than 100 mGy despite relatively long average fluoroscopy times of 8 min; organ doses ranged from 9–26 mGy in the abdomen. The effective dose was 10.7 mSv for analogue radiography decreased by 12% when digital radiography was used although more than 80% of the dose was due to fluoroscopy. In routine CT colonography performed using relatively high mean effective mAs of 119 for the accurate detection of colorectal cancer and extra colonic lesions, organ doses within the primary X-ray beam were between 30 mGy and 44 mGy for paired scans whereas, in a low dose set-up with effective mAs of 27, they were approximately 10 mGy. Effective doses for routine and low-dose CT colonography of 23.4 mSv and 5.7 mSv were about double and half of the doses for barium enemas, respectively.

Durga and Seife, [9] they calculated the collective dose of the population as a result of radiation dose from diagnostic x-rays, thereby to estimate the annual effective dose per patients which would be reduced by the use of rare earth intensifying screen. Data on the number of diagnostic procedures using x-ray examination in year 2010 in one governmental and four private Hospitals by body site were collected in Visakhapatnam. Typical effective doses for those examinations making major contributions to collective was calculated according to the European Guidance on Estimating Population Doses from Medical X-rays .The annual collective effective doses from x-ray diagnostics were obtained by multiplication of the estimated effective doses per examination type with the corresponding annual frequency and summation over all types of examination. The results were then collected and entered into a database for analysis. They found that a total of 46350 (1.2 exams/patient) medical examination were collected in five hospitals in year 2010. The total collective dose to all patients from diagnostic plain x-rays, IVU and Barium studies was 47.3 mSv, this result in an annual effective dose per patient of 1.23 mSv. Lumbar spine and Barium follow accounted 13.65 mSv (28.88%) and 13.08 mSv (27.67%) of the total annual collective dose which results in 15.5% and 2.8% of exposures respectively. They concluded that, although the use of ionizing radiation for diagnostic medical procedures is an acceptable part of modern medicine, there is also the potential for inappropriate use and unnecessary radiation dose to the patient, so the request of high dose procedures must be justified.

Daniel et al, [10] were calculated the collective dose of the population as a result of radiation dose from diagnostic x-rays, thereby to estimate the annual incidence of cancer which would be reduced by the use of rare earth intensifying screen. Data on the number of diagnostic procedures using x-ray examination in year 2007 in nine governmental hospitals, excluding military hospitals, by body site were collected in Addis Ababa. The number of examinations of specific body site was multiplied by the average effective dose per examination to get the collective dose over the population. Based on International Commission on Radiological Protection (ICRP) the fatality risk of fatal cancers (5% per Sv) was estimated. They found that, the annual collective dose over the population is 31.21manSv (0.0.42mSv per person). Based on ICRP fatality risk of 500 fatal cancers per 10,000 man-sieverts (5% per Sv), estimation of incidence of fatal cancers cases in year 2007 was 2 cases half of which can be reduced by adoption of rare earth screens. And they concludes that , Although the use of ionizing radiation for diagnostic medical procedures is an acceptable part of modern medicine, there is also the potential for inappropriate use and unnecessary radiation dose to the patient, so the request of radiography must be justified. It is estimated that the adoption of rare earth screen technology might reduce the annual incidence of cancer which would be fatal after an average latency period of 18.4 years by half, hence this research recommended adopting rare earth screen technology in Ethiopia.

Paydar et al, [11] evaluated the patients ED in digital chest X-ray examinations in Iran. The ED was calculated by using the MCNP Monte Carlo code and an adult hermaphrodite mathematical phantom. The effects of both operating high voltage and projection geometry on the effective dose were investigated. The absolute values of the ED were calculated for digital and conventional Posterior-Anterior (PA) and Lateral (LAT) projections of chest radiography. They found that the ED for PA projection in digital chest radiography in some major hospitals is higher than National Diagnostic Reference Level (NDRL). And they conclude that the optimization process should be considered seriously at national level to reduce patient exposure in digital chest radiography in Iran.

Mark et al, [12] analyzed the total effective dose of radiation that a cohort of orthopedic trauma patients are exposed to during their inpatient hospitalization and determine risk factors for greater exposure levels. They Followed the approval from the Institution Review Board, a search was conducted of a level I trauma centre database for radiation exposures to patients over a 1 year period. Patients were included if they had an ICD-9 code from 805 to 828, indicating a fracture involving the trunk (805–811) or extremities (812–828). We compared the total effective radiation dose in various injury patterns as well as those considered to be polytrauma patients to those who were not according to their injury severity score (ISS). They found that, the records of 1357 trauma patients were available for review. The average patient age was 40.6 years and the mean ISS was 14.1. The average effective radiation dose for all patients during their hospitalization was 31.6 mSv. There was a statistically significant difference in radiation exposure between patients with an ISS greater than 16 (48.6 mSv) versus those with an ISS equal to or less than 16 (23.5 mSv), $p < 0.001$. Patients with spine trauma can be expected to get more than 15 mSv more radiation than non-spine patients, $p < 0.001$. Extremity injuries received the least amount of radiation, spine only patients were next, and then finally spine and extremity injury patients had the greatest exposures. Experience to spine fracture, a pelvic fracture, a chest wall injury, or a long bone fracture were all risk factors for having more than 20 mSv of effective dose exposure. Patients under the age of 18 years did receive less radiation than the remainder of the cohort, $p < 0.001$. And they concluded that the average orthopedic patient receives a total effective radiation dose of more than 30 mSv, which is much greater than the recommended permissible annual dose by the International Commission on Radiological Protection (20 mSv). These findings indicate that the average trauma patient (in particular those with polytrauma or fractures involving the spine, pelvis, chest wall, or long bones) is exposed to high levels of radiation during their inpatient hospitalization. The treating physicians of such patients should take into consideration the large amounts of radiation their patients receive just during their initial hospitalization, and be prudent with the ordering of imaging studies involving radiation exposure.

Kharita et al, [13] evaluated the radiation doses received by adult patients undergoing eight routine common types of X-ray examination in Syria. These types cover chest PA, lumbar spine PA, lumbar spine LAT, urography, abdomen, pelvis and hip, head and shoulder. This work consisted of measurements for 926 X-ray examinations for patients in 26 governmental hospitals. The mean and third quartiles of the dose area product (DAP) to each patient per examination have been measured. The corresponding average effective doses have been computed from the DAP measurement for each examination using NRPP X-Dose software. Comparison of the results was done with those from similar surveys published by the United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000, 2007). They suggest that their measurements can provide a useful baseline to establish, for the first time, national diagnostic reference levels. They concluded that, these results can be used in the future to evaluate the collective dose to the population from medical exposure and the radiation risks from the various radiological procedures.

Walter and Awais [14] determined typical organ doses, and the corresponding effective doses, to adult and pediatric patients undergoing a single CT examination. Heads, chests, and abdomens of patients ranging from neonates to oversized adults (120 kg) were modeled as uniform cylinders of water. Monte Carlo dosimetry data were used to obtain average doses in the directly irradiated region. Dosimetry data were used to compute the total energy imparted, which was converted into the corresponding effective dose using patient- size- dependent effective –dose -per- unit- energy imparted coefficients.

Representative patient doses were obtained for scanning protocols that take into account the size of the patient being scanned by typical MDCT scanners. They found that, Relative to CT scanners from the early 1990s, present-day MDCT scanners result in doses that are 1.5 and 1.7 higher per unit mAs in head and body phantoms, respectively. Organ absorbed doses in head CT scans increase from 30 mGy in newborns to 40 mGy in adults. Patients weighing less than 20 kg receive body organ absorbed doses of 7 mGy, which is a factor of 2 less than for normal-sized (70-kg) adults. Adult head CT effective doses are 0.9 mSv, four times less than those for the neonate. Effective doses for neonates undergoing body CT are 2.5 mSv, whereas those for normal-sized adults are 3.5 mSv. And they concluded that the Representative organ absorbed doses in CT are substantially lower than threshold doses for the induction of deterministic effects, and effective doses are comparable to annual doses from natural background radiation.

Osman et al, [15] evaluate patient's radiation dose in routine X-ray examinations in Omdurman teaching hospital Sudan.110 patients was examined (134) radiographs in two X-ray rooms. Entrance surface doses (ESDs) were calculated from patient exposure parameters using Dos Cal software. The mean ESD for the chest, AP abdomen, AP pelvis, thoracic spine AP, lateral lumbar spine, antero-posterior lumbar spine, lower limb and for the upper limb were; 231±44 μGy,453±29 μGy, 567±22μGy, 311±33 μGy,716±39 μGy, 611±55μGy, 311±23 μGy, and 158±57 μGy, respectively. Data shows asymmetry in distribution.

The results of were comparable with previous study in Sudan. Hilman and Drew in [16] determined the amount of cumulative effective dose received by adult trauma patients presenting to emergency department during the first 24 hours of their care. Emergency department records for trauma patients presenting to the Canberra hospital (ACT, Australia) between 1st January and 31st December 2008 were retrospectively reviewed for all diagnostic (plain radiographs and Computed Tomography (CT) scans) imaging performed on adult (>18 years old) trauma patients who arrived directly from the scene of injury within the first 24 hours from arrival. Estimated radiation dose was used to calculate the total radiation dose for each individual, they found that a total of 118 patients met the inclusion criteria and were assessed for radiation dose. The mean effective dose received by trauma patients was 11.3 mSv; with CT–scan contributing the majority (94%) of the total radiation dose. 42% (50 patients) of the patients received less or equal to 5 mSv from their initial 24 hours assessment in the emergency department while around 26% (31 patients) received between 25 mSv to 30 mSv radiation dose from diagnostic imaging, and concluded that the Trauma patients presenting to emergency department receive significant effective dose from diagnostic imaging during their first 24 hours assessment. One in three patients received 25 mSv to 30 mSv effective dose, ten times higher than the background radiation of 3 mSv. This is a small but assessable excess cancer risk considering this is only the first 24 hours stay in the emergency department. The benefits of diagnostic radiologic investigations should be weighed with the radiation risk associated. Unnecessary imaging, especially CT scan, should be avoided.

Tsapaki et al, [17] aimed to derive a mathematical method for calculating the entrance surface dose (ESD) from exposure factors for all tube potentials used in clinical practice and to compare the calculated ESDs (ESDC) with those measured ESDTLD) using thermo luminescent dosimeters (TLDs). The exposure parameters of 43 patients who underwent (a) posteroanterior (PA) and lateral (LAT) chest examination (13 patients), (b) supine abdomen (10 patients), (c) erectus abdomen (10 patients), or (d) urinary tract examination (10 patients) were recorded. Patient ESD was directly measured by TLDs and calculated from exposure factors. The differences between ESDC and ESDTLD were quite small and could be explained by the uncertainties involved in both methods, in all but the PA chest examination where the ESDC was about 50% larger than ESDTLD. However, in PA chest the ESDTLD was close to the minimum detectable dose of TLDs, questioning the accuracy of ESDTLD. Further investigation showed that using the high tube potential technique (130 kV) in the PA chest examination resulted in very short exposure times, in the region of 4 ms. In such short exposure times, the X-ray generator operation presented stability problems that led to loss of output linearity and consequently to false calculation of ESD. The calculation method offers a reliable and cheap alternative to the measurement of ESD by TLD, provided that the exposure times are not as short as in the PA chest examinations recorded in this study, so that the output linearity with tube current–time product (mAs) is maintained.

Johnston and Brennan [18] establish, for the first time, a baseline for national reference dose levels in Ireland for four of the most common X-ray examinations: chest, abdomen, pelvis and lumbar spine. Measurements of entrance surface dose using thermoluminescent dosimeters (TLDs) for these four X-ray examinations were performed on 10 patients in each of 16 randomly selected hospitals. This represented 42% of Irish hospitals applicable to this study. They found that there is a wide variation of mean hospital doses, from a factor of 3 for an anteroposterior lumbar spine to a factor of 23 for the chest X-ray. The difference between maximum and minimum individual patient dose values varied up to a factor of 75; such variations were so complex and ascribed to general, low tube potential, high mAs and low filtration were which in turns leads to high-dose hospitals and also demonstrated lower reference dose levels of up to 40% when compared with those established by the UK and the

Commission of the European Communities for four out of six projections. Only the chest X-ray exhibited a similar reference level to those established elsewhere. This emphasizes the importance of each country establishing its own reference dose levels that are appropriate to their own radiographic techniques and practices in order to optimize patient protection.

Bogucarskis et al, [19] estimated the doses received by patients undergoing radiological examinations in order to establish dose reference levels (DRLs) in Latvia. Several large hospitals, small hospitals and private practices were selected for patient dose measurements. The measurements were carried out using calibrated thermoluminiscence dosimeters attached to the patient's skin. Exposure parameters and patient's data were recorded. The entrance surface doses (ESDs) to patients undergoing several common X-ray examinations (chest AP/PA, chest LAT, lumbar spine AP/PA, lumbar spine LAT and pelvis) were measured. Data concerning the kV (p) settings, used type of films, focus-film distance and the ESD values were analyzed and compared with those recommended by the European Community (EC). Among the different hospitals and private practices, discrepancies in the patient doses and techniques used for the examination were found, where the doses exceeded the EC recommended values owing to a very low kV (p) and a very low sensitivity of the screen film combinations used.

Justin and Peter, [20] determine the magnitude of radiation doses received by selected radiosensitive organs of patients undergoing CT examinations and compare them with other studies, and second, assessed how CT scanning protocols in practice affect patient organ doses. Patient organ doses from five common CT examinations were obtained from eight hospitals in Tanzania. The patient organ doses were estimated using measurements of CT dose indexes (CTDI), exposure-related parameters, and the impact spreadsheet based on NRPB conversion factors. A large variation of mean organ doses among hospitals was observed for similar CT examinations. These variations largely originated from different CT scanning protocols used in different hospitals and scanner type. The mean organ doses in this study for the eye lens (for head), thyroid (for chest), breast (for chest), stomach (for abdomen), and ovary (for pelvis) were 63.9 mGy, 12.3 mGy, 26.1 mGy, 35.6 mGy, and 24.0 mGy, respectively. These values were mostly comparable to and slightly higher than the values of organ doses reported from the literature for the United Kingdom, Japan, Germany, Norway, and the Netherlands. It was concluded that patient organ doses could be substantially minimized through careful selection of scanning parameters based on clinical indications of study, patient size, and body region being examined.

Salottolo et al, [21] quantified the cumulative effective dose of radiation received during hospitalization after traumatic injury and to compare the computed tomography (CT) utilization practices for two time periods in patients with trauma. Consecutively admitted adult patients with trauma with moderate to severe injuries (injury severity score >8), an intensive care unit (ICU) length of stay of one or more days, who were directly admitted and not transferred to another acute care center. CT examination means and utilization were compared for April through August, 2003 and April to August, 2007. Cumulative effective doses were calculated for the 2007 period, and patients with a high radiation dose (>100 mSv) were identified. One hundred sixty-five adult patients with trauma were included. An increase in mean CT examinations per patient was observed in the 2007 period compared with the 2003 period, overall (4.41 vs. 3.44, p = 0.002) and among subsets of patients. The overall increase remained significant after adjustment for patient demographics (p = 0.05). The mean cumulative effective dose per patient was 11.13 mSv in 2007; 9% of patients received a dose > or =100 mSv. They concluded that Patients with trauma are at an increased risk of adverse effects from CT studies, because they receive high doses of radiation, and the number of CT examinations that patients receive is increasing with time. We recommend that risk of radiation be prospectively monitored and estimated by hospitals through the use of CT examination count per patient.

Leswick et al, [22] calculated the effective dose from diagnostic computed tomography (CT) scans in Saskatchewan, Canada, and compare with other reported dose levels. They collected the Data from CT scans from 12 scanners in 7 cities across Saskatchewan. The patient age, scan type, and selected technique parameters including the dose length product and the volume computed tomography dose index were collected for a 2-week period. This information then was used to calculate effective doses patients are exposed to during CT examinations. Data from 2,061 clinically indicated CT examinations were collected, and of them 1,690 were eligible for analysis. Every examination during a 2-week period was recorded without selection. They found that The average provincial estimated patient dose was as follows: head, 2.7 mSv (638 scans; standard deviation [SD], +/-1.6); chest, 11.3 mSv (376 scans; SD, +/-8.9); abdomen-pelvis, 15.5 mSv (578 scans; SD, +/-10.0); abdomen, 11.7 mSv (80 scans; SD, +/-11.48), and pelvis, 8.6 mSv (18 scans; SD, +/-6.04). Significant variation in dose between the CT scanners was observed (P = .049 for head, P = .001 for chest, and P = .034 for abdomen-pelvis). And concluded that: the Overall estimated dose from diagnostic CT examinations was similar to other previously published Canadian data from British Columbia. This dose varied slightly from some other published standards, including being higher than those found in a review conducted in the United Kingdom in 2003.

Aldrich et al, [23] estimated the diagnostic reference levels and effective radiation dose to patients from routine computed tomography (CT) examinations in the province of British Columbia, Canada. The patient weight, height and computed tomography dose index or dose linear product (DLP) were recorded on study sheets for 1070 patients who were referred for clinically indicated routine CT examinations at 18 radiology departments in British Columbia. Sixteen of the scanners were multi detector row scanners. They found that, the average patient dose varied from hospital to hospital. The largest range was found for CT of the abdomen, for which the dose varied from 3.6 to 26.5 (average 10.1) mSv. For head CT, the range was 1.7 to 4.9 (average 2.8) mSv; for chest CT, it was 3.8 to 26 (average 9.3) mSv; for pelvis CT, it was 3.5 to 15.5 (average 9.0) mSv; and for abdomen-pelvis CT, it was 7.3 to 31.5 (average 16.3) mSv. Reference dose values were calculated for each exam. These DLP values are as follows: head, 1300 mGy cm; chest, 600 mGy cm; abdomen, 920 mGy cm; pelvis, 650 mGy cm; and abdomen-pelvis, 1100 mGy cm. And they concluded that, among hospitals, there was considerable variation in the DLP and patient radiation dose for a specific exam. Reference doses and patient doses were higher than those found in similar recent surveys carried out in the United Kingdom and the European Union. Patient doses were similar to those found in a recent survey in Germany.

Sulieman et al, [24] quantified the patients' radiation doses during barium studies and estimated the organ equivalent dose and effective dose with those procedures. A total of 33 investigations of barium studies were measured by using thermo-luminescence dosimeters. The result showed that the patient entrance surface doses were 12.6 ± 10, 44.5 ± 49 and 35.7 ± 50 mGy for barium swallow, barium meal, follow through and enema, respectively. Effective doses were 0.2, 0.35 and 1.4 mSv per procedure for barium swallow, meal and enema respectively. Radiation doses were comparable with the previous studies. A written protocol for each procedure will reduce the inter-operator variations and will help to reduce unnecessary exposure.

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