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OPTIMIZATION OF RADIATION DOSE AND EFFECTIVE DOSE FOR CT PELVIS EXAMINATIONS IN TWO MAIN HOSPITALS IN TAIF REGION

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Abstract:

Introduction: *CT scan is one of the medical imaging methods that irradiate patients with significant amounts of radiation. These amount of radiation doses must be well estimated if the imaging area is in part containing radiation-sensitive organs such as the pelvic area.*

Objectives: *the objectives of the current study were to assess radiation dose during pelvis CT imaging and estimate the effective dose as well as to propose diagnostic reference level (DRL).*

Methodology: *200 adult patients irradiated in two major governmental hospital in Taif city, Saudi Arabia, patients' demographic data from was collected such as weight, height, and age. Scanner specifications and scan parameters for each pelvis examination were recorded in special data collection sheet. Volume CT dose index (CTDIvol and dose length product (DLP) were utilized to estimate the radiation dose and effective dose. Microsoft Excel was used to analyse the data.*

Main Results: *there was variation in scanning parameters among two hospitals under study and this result in variation in effective dose between two hospitals. The average DLP, CTDIvol and effective dose were 368.5, 390.7 mGy-cm,10.2,10.8 mGy and 7, 7.4 mSv for hospital one and two respectively.*

Conclusion: Based on the third quartile of DLP and CTDIw, the recommended DRL for both hospitals was 405 mGy-cm and 21.75 mGy, respectively. The findings revealed a reduced effective dose value when compared with previous studies.

Key Word: CT, radiation dose, pelvis, Taif

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INTRODUCTION:

One of the most significant developments in modern medicine has been the advent of computed tomography (CT) scanners. In 1972, they were first used in clinical practice (Johns and Cunningham, 1983). CT (computed tomography) is a method of imaging that generates body-slice data in a three-dimensional format. CT scans have a better contrast resolution than planar radiography, allowing for a greater capacity to detect tiny variations in tissue attenuation (contrast) (Shrimpton and Wall., 1995). CT now enables for sub-millimeter resolution imaging of the entire body in 5-20 seconds (Hausleiter et al., 2009). CT delivers high-quality cross-sectional pictures, and its widespread use has had a significant impact on patient care as well as population exposure to medical X-rays (Alkadhi and Euler., 2020). CT examinations have different exposure conditions than conventional X-ray techniques. National surveys on CT practice have revealed that CT' is becoming a more major source of medical X-ray exposure (Alkadhi and Euler., 2020). Due to rapidly with the advent of CT technology and its widespread use, CT scanners currently account for around 40% of medical X-ray exposure in the public, (Brix et al., 2003). The best use of ionizing radiation necessitates the collaboration of three crucial elements of the imaging process. Image quality, radiation dose to the patient, and examination technique selection are all factors to consider (Tsapaki et al., (2001). One of the fundamental concepts of radiation protection is to limit the dosage to the patient as low as reasonably achievable (ALARA) while still meeting the clinical purpose (Treier, et al., (2010).

The International Commission on Radiological Protection has suggested that efforts be made to reduce CT radiation (ICRP). The International Commission on Radiological Protection, the International Atomic Energy Agency, and the European Commission have all recommended the establishment and implementation of CT dose guidance levels for the most common CT examinations to promote radiation dose optimization strategies.

Patient dose optimization is a legal responsibility to guarantee that the radiation dose for each medical exposure at (ALARA principle) while still achieving the desired diagnostic or therapeutic result . Direct measurement of patient dose and the formation of diagnostic reference levels (DRLs) are essential to achieve optimization, both of which are regulatory requirements (Vano, et al., 2015).

There is an implied necessity for each radiological examination to ensure that the patient benefit outweighs any associated radiation risk (Vano, et al., 2015). As a result, practitioners must be aware of the amount of radiation hazards involved with radiological investigations, as well as how these risks fluctuate with patient demographic characteristics such as gender and age.

There are many ways and technique available to estimate CT dose for patients, one of these ways to consider the index of CT dose (CTDI either weighed CT dose or volume CT dose and the parameter of dose length product.

The volume CT dose index (CTDJvol) and the dose length product (DLP) are presented to operators during CT exams. CTDI is a measure of the amount of radiation required to do a CT examination that is independent of the scan length. Multiplying CTDI by the relevant scan length provides DLP, which may be used to calculate the total amount of radiation used to perform a CT examination. The amount of radiation absorbed by the patient, on the other hand, is determined by the patient's physical attributes and the type of CT examination.

A literature review revealed the need to determine the optimal radiation dose and effective dose during CT pelvis. There is a need for a unified protocol for hospitals in the form of a local DRL. The recent increases in exposure to radiation during CT and the large differences in radiation dose due to protocols and scanner-dependent factors support the need as well. Moreover, in Saudi Arabia, so far, no systemic measurement methods have been developed to comply with the international regulations on radiological protection. Therefore, it is recommended that DRLs should be based on data from more than one facility in order to provide a representative sample over equipment types. Through this study, we will attempt to establish a local DRL for the three hospitals in Taif. It is hoped that this study would then be expanded to establish separate regional reference levels followed by a Saudi national reference level that is consistent with international recommendations.

The current objectives of this manuscript were to evaluate the radiation dose for CT pelvis., estimate the effective radiation dose during CT scan for pelvis examination. And propose local diagnostic reference level for hospitals under investigation

MATERIALS AND METHODS:

Data were collected for 200 patients from two hospitals: The hospitals that participated in the study

are: King Abdul Aziz specialist hospital (KAASH), and King Faisal Medical Complex (KFMC) at Taif city Saudi Arabia.
Firstly, each hospital's radiographers were required to disclose information on their CT scanners. The following information was gathered (table 1 shows CT machines specifications): Name of the hospital, manufacturer of the CT machine, type of machines according to number of slices produced, model, year of installation, type, last date of quality control (QC) check for spiral CT scanners used in both hospitals.
Both of machines display DLP and CTDI during the scan and record this facility during imaging achieving

Table 1: Specifications of Machines Used in Data Collection

Hospital	Manufacturer	Type	installation	Previous QC check
KAASH	Siemens	Spiral/ 128	2011	September 2021
KFMC	Philips	Spiral/128	2016	October 2021

The study examined on 200 adult patients who had pelvic CT scans at two multi-slice computed tomography (MSCT) facilities. The hospitals were in Taif, in the western region of Saudi Arabia. The two hospitals chosen were government hospitals that serve the highest population density and provide diagnostic services to a huge area around them. These hospitals were chosen because they are among the busiest in terms of patient volume. Patients were chosen in order, and dosage information was taken from the archive of exams conducted between June 1 and October 31, 2021. 116 patients' data were acquired from KAASH, while 84 patients' data were collected from KFMC. All of the participants in the study were adults, with a mix of male and female patients undergoing CT scans for various clinical purposes.

Inclusion and exclusion criteria
Inclusion criteria include any adult patient's female or male during the data collection phase requested CT pelvis exam in hospitals under study.

Exclusion criteria include paediatric patient requested CT pelvis during the data collection phase requested CT pelvis exam in hospitals under study.

Patients' characteristic such as age weight and gender were collected in special data collection sheet. Body mass index then calculated by dividing the square of height in centimetre by weight in Kg.

$$BMI = L2/Kg \qquad (1)$$

Patients dose calculation
Patient information (age, gender and weight), tube voltage, tube current, rotation time(s), pitch value, and CTDIvol, and Were obtained from patients underwent CT pelvis examinations and some of patients underwent pelvis examination their data achieved from the DICOM.

We used digital callipers on the scanner console to measure the diameter of the patient's images for size specific dose estimate (SSDE) estimations. Anterior-Posterior diameter (DAP) and lateral diameter (DLAT) were measured on transverse CT images from the mid-slice position, and DLAT on scout images. As patient size markers, measured dimensions (DAP and DLAT) were used:

The effective diameter was achieved using equation 3-3 which obtained from report of AAPM No 204.

$$Effective\ diameter = \sqrt{DAPXDLAT} \qquad (2)$$

(AAPM ,204)
The SSDE was then determined by multiplying the CTDIvol presented on the console by the size-specific conversion factors (f) listed in AAPM report 204.

$$SSDE = CTDIvol\ X\ F \qquad (3)$$

(AAPM,204)

Then comparison is made between SSDE, CTDIvol achieved in present study with previous studies in literature Also correlation of SSDE and CTDIvol is found.

The CT examination DLP was multiplied by a k-coefficient derived from a table provided by ICRP 102, to estimate effective dose, as illustrated in equation 3-5.

$$Effective\ dose = DLPXK \qquad (4)$$

(ICRP,102)

More information can be found at https://www.ajronline.org/doi/full/10.2214/AJR.14.13317

Also, the weighted CT dose index is calculated using the below equation (equation 3-6) that achieved from AAPM report 204.

$$CTDIw = CTDIv\ X\ Pitch \quad (5)$$ (AAPM, 204)

Recognize that in CT, spiral pitch is inversely proportional to CT radiation dose. The spiral pitch is calculated by dividing the table movement (input into the gantry) by the collimator width for each gantry rotation.

Data management and analysis were performed using Microsoft MS Excel version 2010.

Ethical considerations

Ethical approval was taken from the Ministry of health Taif and then from each hospitals KAASH and King Faisal complex building, then the administrator focused the researcher to department un each above hospitals to start the data collection phase.

RESULTS:

The objectives of current study were to assess the pelvic radiation dose in computed tomography for two main hospitals in Taif city and compare the results with literature available, as well as to establish local diagnostic reference level for the local practice.

Sample size

There were 200 patients distributed between male (94), which represented 47% and female (106), which represented 53%., Figure 4-1-1 shows the frequency distribution of sample size. There is no wide variation between gender participated in this study, so the sample can be considered as homogeneous sample.

Table 2 Statistic variation of age, weight and BMI among study sample

Parameter	mean	Max	Min	±STD
Age (year)	37.3	82	20	12.9
Weight (Kg)	69.2	79	46	10.3
BMI (Kg/m^2)	25.5	30.6	18.5	4.7

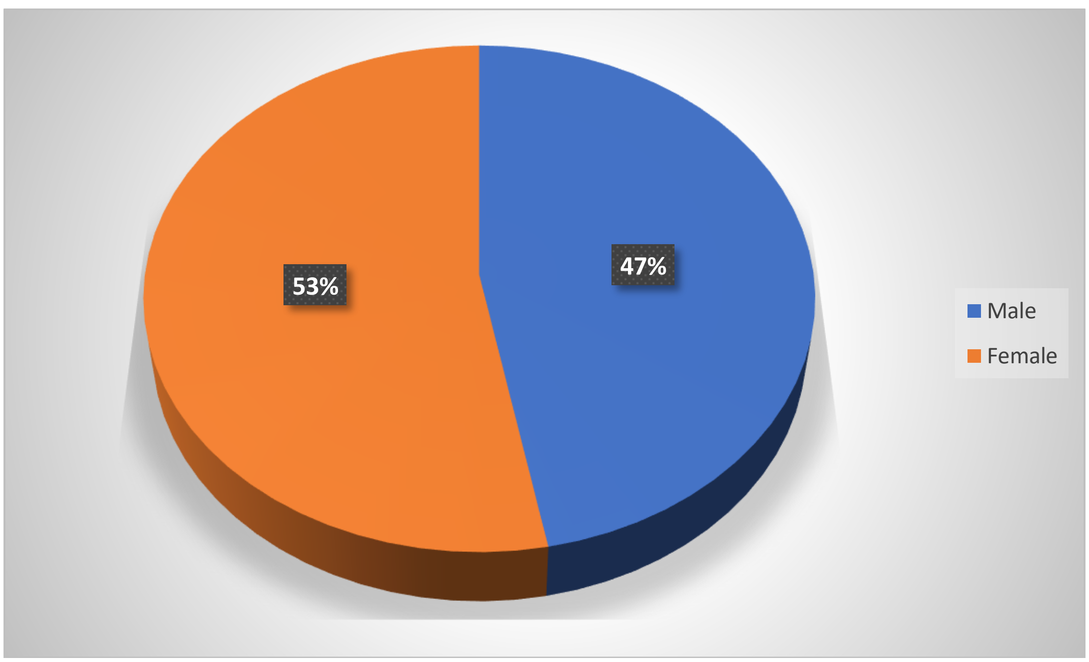

Figure 1 shows the frequency of gender among sample size participated in the study

The average age and body mass index among participants in this study was 37.3 years. and 25.5 (Kg/m^2) respectively Table 2 shows the statistical variation of age,weight and BMI.

There was wide range of age among adult participant (20-82Y) and less range of BMI among those participants (18.5-30.6 Kg/m^2). This will Give us better distribution about radiation dose among participants. The average weight shows less than standard man described by ICRP 1977 (ICRP 1977) which showed the reference weight of 70 Kg. data for the above table (Table 4-1) was statistically calculated for two hospitals.

Indication of CT pelvis examinations

For specific conditions, a CT scan of the pelvis or abdomen/pelvis is performed. These scans were performed for diagnosis and evaluating the following conditions:

Aneurysms of the abdominal aorta, Cancers of the liver, kidney, pancreas, ovary, or bladder in the pelvic region Crohn's disease, pancreatitis, liver cirrhosis, ulcerative colitis, and other inflammatory disorders are examples of inflammatory diseases. Injuries to the liver, kidneys, spleen, or other abdominal organs are among the most common. Stones in the renal or bladder Pancreatitis, and Appendicitis, pyelonephritis, and pelvic inflammations are examples of pelvic infections.

Figure 2 summarized the indications of CT pelvis examination throughout this study

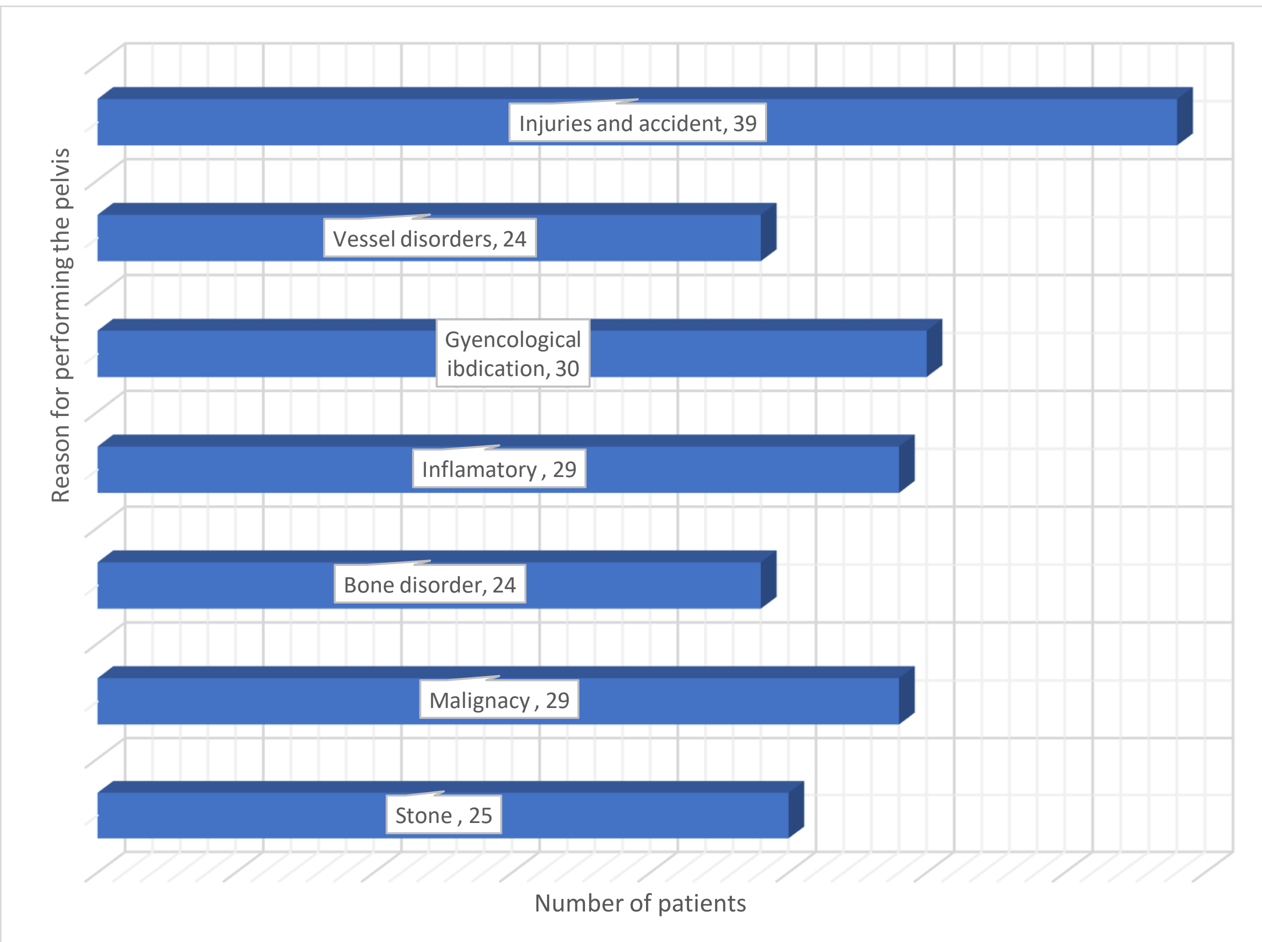

Figure 2 Reasons for performing CT pelvis examination against the number of patients

From the figure 4-2 showed that the highest indication for pelvis examination was the injuries and accidents and this may due to type or nature of hospitals under study as they were the main governmental hospitals in Taif city and received mostly emergency cases that required irradiation to diagnose their injuries.

Dosimetry and exposure factors

The exposure factors and patients characteristic (age and weight) for pelvis examination were recorded, the following table (Table 3) shows the slice thickness (ST), number of slices (NS), pitch, product of tube current and time and tube kilovoltage, for hospital one and two. The sample size in hospital one was 91, while for hospital two was 109 patients.

Table 3- Descriptive statistics of patient's characteristics in each hospital and the scan parameters for pelvis examination

Hospital 1							
	Patients' characteristics		**Scan parameters**				
	Age (year)	Weight (Kg)	Kv	mAs	ST (mm)	NS	Pitch
Mean	42.8	68.7	120	190.6	5.4	18	1.8
Median	47	74	120	340	6	16	1.9
Max	71	78	120	642	8	24	1.9
Min	24	57	120	49	.1	12	1.25
Sample size	91						
Hospital 2							
	Patients' characteristics		**Scan parameters**				
Parameter	Age	Weight	kV	mAs	ST (mm)	NS	Pitch
Mean	55.4	69.3	120	224.5	6.2	16	1.4
Median	61	72	120	420	8	20	1.5
Max	82	79	120	680	10	32	1.8
Min	20	46	120	80	1.5	10	0.8
Sample size	109						

kV tube potential, mAs tube current, ST slice thickness, and NS describes number of slices

Patients' dosimetry

The DLP, CTDIv were recorded, also calculated values of CTDIw and SSDE gathered using equation 3-5 and 3-6, The statistic of DLP and CTDI in each hospital were summarized in table 4.

Table 4 Descriptive statistics of DL P, CTDIvol, CTDIw and SSDR

Hospital 1					
Parameter	Mean	3rd quartile	Max	Min	±STD
DLP (mGy-cm	368.5	390	420	159	12.4
CTDIvol (mGy)	10.2	11.2	12.1	9.2	1.7
CTDIw (mGy)	18.3	20.5	23	11.6	3.8
SSDE (mGy)	24.4	32.6	40.4	18.2	4.8
Hospital 2					
parameter	Mean	3rd quartile	Max	Min	±STD
DLP (mGy-cm	390.7	420	442	192	13.1
CTDIvol (mGy)	10.8	11.9	13	9.5	1.5
CTDIw (mGy)	20.5	23	26	14.3	4.5
SSDE (mGy)	25.4	34.7	42.8	19.6	2.8

The above table (Table 4) showed variation of practice among two hospitals and consequently variation in radiation dose during the pelvis procedure.

The below figure (Figure 3) summarized the comparison of average value of DLP, calculated CTDI and SSDE achieved in two hospitals participated in this research.

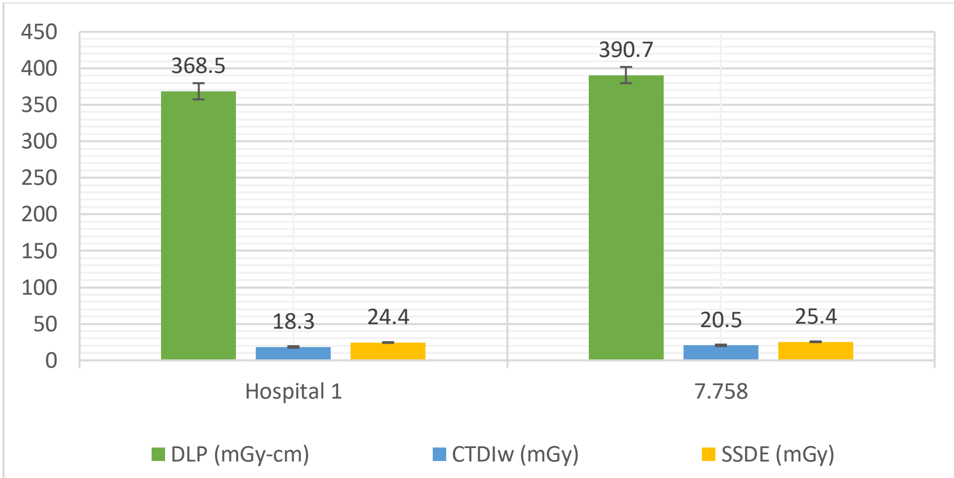

Figure 3- Comparison of DLP, CTDIw and SSDE in two hospitals

The correlation of CTDIw and SSDE plotted in Figure 4 showed there was linear correlation between SSDE and CTDIw, and the correlation coefficient was 0.6 (R^2=0.6).so the two quantities are strong dependent.

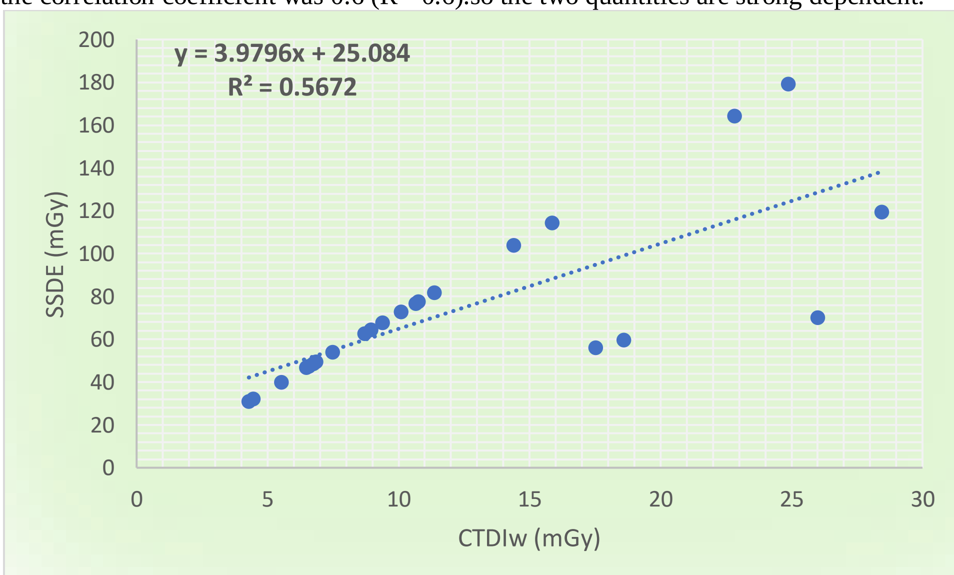

Figure 4 CTDIw versus SSDE in both hospitals

Effective radiation dose for CT pelvis examination

To estimate effective doses from patient examinations, the DLP of each examination was multiplied by previously established conversion factors for a 70-kg male (ICRP, 102; Osman et al., 2020) with this conversion factor being 0.019 mSv/mGy cm for the pelvis and 0.017 mSv/mGy cm for the abdomen-pelvis.

Study limitations

Short of period allowed for data collection and consequently the data collected for the current study is limited. For future study we suggest to include contrast media images to be considered for estimating the DRL for them. Also, an ethical approval took long time to be signed and administrator agree to perform the thesis in selected hospitals.

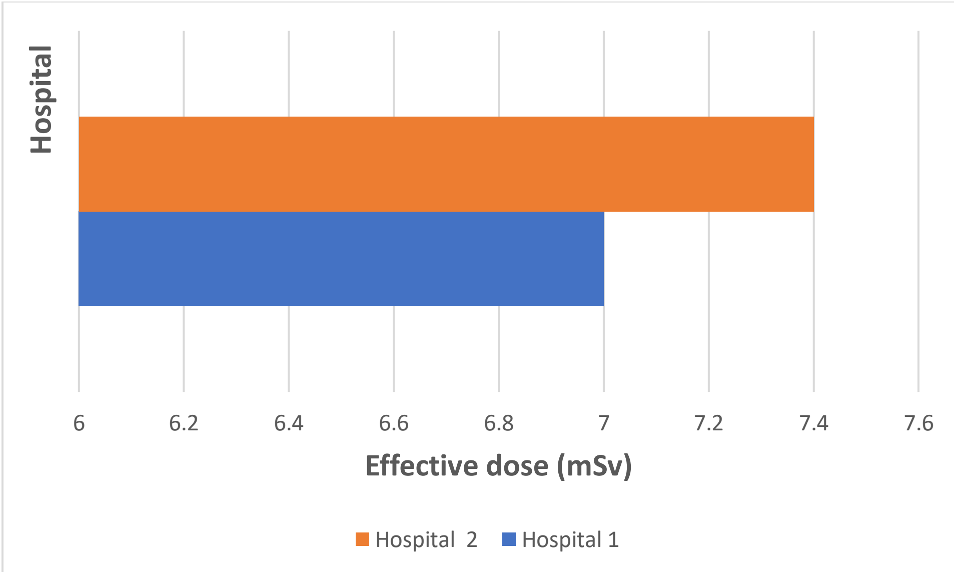

Figure 5 Comparison of effective dose in both hospital

There was no wide variation in both hospital in term of effective dose and the average of effective dose was 7.21 mSv.

DISCUSSION:

The current research was to evaluate the radiation dose during CT pelvis examination in two main hospitals in Taif, Saudi Arabia, as well as to estimate effective dose, in addition to propose diagnostic reference level in a forementioned procedure. The sample size from these hospitals was 200 adult patients underwent CT pelvis examination, 53% was female and 47% was male. The average age, weight and body mass index among the participants in this research was 37.2 years,69.2 Kg and 25.5 Kg/m2 respectively, so according to ICRP 60 (ICRP 60.,1991) the weight and BMI in this study can be considered as normal weight man, and therefore for estimating the effective dose in this study, the researcher used the conversion coefficient from their publication of normal weight patients. on publication of ICRP 1990 (ICRP 1990) the normal weight man was 70 Kg and in current study it was 69.2.

There were different reasons to request CT pelvis in hospitals in our study which ranged range from plain CT to complicated CT procedure using contrast agent. For our study the most highest reason to request CT was for diagnosing injuries and accident (39 patients) that represented 19.5% from all participants, and the second reason was for gynecological purpose (30 patients that represented 15% (Figure 4-2), This may be attributed to the fact that the two hospitals chosen to conduct this study are considered two major hospitals that receive a huge number of accidents and emergencies and cover a large number of residents in the city of Taif, in addition to the fact that most of the accidents require CT scans in addition to routine X-rays as part of the emergency work protocol.

In our study when comparing the pitch in each hospital we concluded that the H**ospital two** irradiates patient with higher value of pitch than hospital one, and this will definitely affect the amount of radiation dose received by patients in the **Hospital number two** compared to **Hospital One**. These findings are similar to Mahadevappa (Mahadevappa et al., 2001) in their original report described the relationship between pitch and patient radiation dose, it mentioned that when increasing the pitch the radiation dose received by patient will decrease, and consequently the pitch and radiation dose inversely proportion, so, this might be the reason that we estimated the radiation dose in the Hospital one less than in the Hospital two.

Our study demonstrated the average value of DLP in the Hospital two was higher compared to the Hospital one, this may be attributed to average pitch used in hospital one which was lower than hospital two as well as number of slices and mAs encountered. When we compared the average DLP in our study with previous studies (Shrimpton et al., 2003, Tsapaki et al., 2001) the current recorded finding showed lower value than previous studies, and this might be due to that the chosen hospital used modulated mA during CT gantry rotation, and this technology may be absent in previous studies.

Our study also showed SSDE and CTDIw was higher for the Hospital two compared to the Hospital one. There was significant correlation of SSDE and CTDIw with the correlation coefficient achieved was 0.6 (R^2=0.6) in our study. This suggests that CTDIw effect directly the amount of radiation dose received by patients during CT pelvis. The CTDIw our study was lower than previous studies value for pelvis CT examination (Tsai et al., (2007); Trier et al., (2010)). According to Livingston (Livingston et al., 2009) they reported that, if proper work standards are followed by workers operating the CT machine, dose reduction is achievable with their CT scanners. When compared to the weight-based strategy, the dose modulation methodology is a more effective method of controlling dose for patients undergoing CT scans. In our study CT machines used in the two hospitals equipped with mA modulation strategy thus resulted in reduction of CT radiation dose as demonstrated by lower CTDIw values.

The effective dose was estimated using **equation 4**, the conversion factor between effective dose and DLP was extracted from ICRP 102 (ICRP 102). The conversion factor varied in different previous studies (Deak et al., 2010; Sahbaee, et al., 2014) and this factor depends mainly on patient characteristic such as weight and body mass index. The average effective dose in our study was 7 and 7.4 mSv for the Hospital one and the Hospital two respectively. In comparison to study by Nwokorie et al (Nwokorie et al., 2017) they reported the range of effective dose to pelvis and abdomen from 8-14 mSv, so, the current study showed less value for pelvic effective radiation dose. This difference may be attributed to their patient's size and protocol applied during their scan or even scanner characteristics. The average of effective dose achieved in two hospitals under study compared to previous studies is given as **Figure 6**

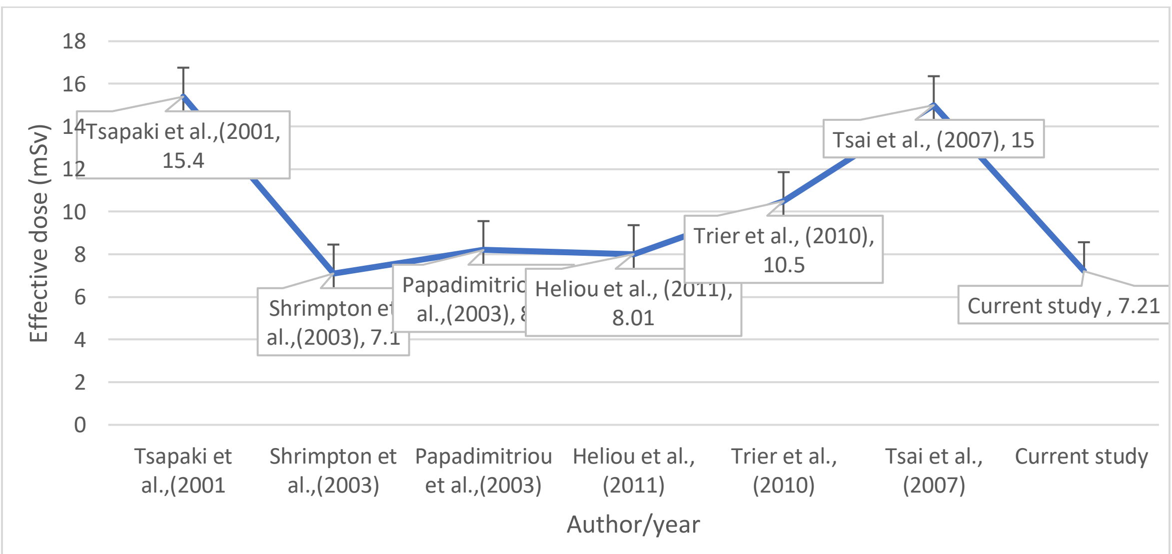

Figure 6 comparison of effective dose in current studies with previous studies

DRLs are a useful tool for promoting optimization. It's important to realize that DRLs are mostly just one portion of the overall optimization process. DRLs are a basic guidance for clinical procedures that do not apply to specific patients or investigations. DRLs should be established for representative examinations or procedures carried out in the local area, country, or region in which they are used. The third quartile values (the values that separate the top 25% of data from the other 75% of data) of these national distributions are typically used as NDRLs. As a result, NDRLs aren't optimal doses, but they can assist identify potentially anomalous practices (healthcare facilities where median doses are among the highest 25 percent of the national dose distribution). DRLs can also be established for a specific region within a country or, in rare situations, for multiple countries. For current study the third quartile of DLP and CTDIw is selected to establish local diagnostic reference level for the practice of CT pelvis in selected hospitals.

CONCLUSION:

The current research revealed that accident and emergency causes were the most common reasons for CT pelvis imaging at two large hospitals in Taif, Saudi Arabia. The radiation dose during the procedure was also investigated, and the average DLP, CTDIw, SSDE, and effective dose for both hospitals were

379.6 mGy-cm, 19,4 mGy, 24.9 mGy, and 7,2 respectively. The proposed DRL for both hospitals were 405 mGy-cm and 21.75 mGy, respectively, based on the third quartile of DLP and CTDIw. In compared to previous studies, the research found a lower effective radiation dose value.

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