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Towards the Establishment of Diagnostic Reference Levels in Saudi Arabia: Review and Opinion

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THIS STUDY aims at providing an overview and evaluation of the current situation of the national Diagnostic Reference Levels (DRLs) in Saudi Arabia**.** Studies published in Pubmed and Google-Scholar, since the DRLs were proposed, are reviewed and general considerations are highlighted, by reviewing some established international DRLs, regarding x-rays and nuclear medicine modalities. The importance of national DRLs (Saudi DRLs) is introduced and discussed. An overview of some studies on Saudi DRLs regarding selected procedures is presented and the validity of radiation dosimetry studies for establishing Saudi DRLs is discussed. The establishment of DRLs for pediatric patient procedures is introduced, discussed and emphasized. An enormous amount of work is required to establish the Saudi DRLs for different procedures, as more than 90% of the work has not been accomplished. Collaboration between researchers is necessary to allow comparisons of DRLs results and to validate the establishment of Saudi DRLs. Furthermore, DRLs for pediatric patient procedures should take priority.

Keywords: Adults, DRLs, Nuclear Medicine, Pediatrics X-rays.

Introduction

The principles of radiation protection are applied to occupational and public radiation exposure that are well-known principles and summarized as three keywords: dose justifications and dose optimization and limitations (ICRP, 2007). Though there is no dose limitations applied to patients undergoing radiation procedures, justification and optimization that are the main concerns in terms of patients' radiation protection (Moores, 2017). To justify the diagnostic and therapeutic radiation practice, its benefits should outweigh any harm to individuals and society, and the cost and benefits of the practice should be considered. In addition, justification of certain radiation procedures is the responsibility of well-trained medical practitioners (ICRP, 2007). To optimize patient radiation protection and image quality, several techniques are used; for example, correct patient positioning andusing optimum exposure factors and radiation collimation devices (Bushong & Stewart, 2017). However, methods and specific standards of adequate image quality are unspecified; these should be determined by radiologists and related health professional practitioners (Rehani, 2015). In addition, scoring sheets of acceptable image quality could be helpful; for example, scoring the image quality in Visual Analogue Scale (VAS) from 1 to 10, where a score over 6 is considered to be adequate. Nevertheless, image quality is a priority, though the radiation dose will be lower with lower image quality (Torres et al., 2010).

Diagnostic Reference Levels (DRLs) concept was introduced as a reference tool to promote optimization of patient radiation dose. DRLs concept was presented by the International Commission on Radiological Protection (ICRP) in 1996 in ICRP Publication 73, then further developed and guidance for practical work was produced in 2001 (Wall & Shrimpton, 1998; Wall,

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2001). Furthermore, the establishment of DRLs in various countries worldwide was encouraged. The IAEA and ICRP suggested three criteria for the DRL establishment priority for such a radiological procedure: patient radiation dose, procedure frequency and patient age. The frequent radiological procedure with high radiation dose for young patient (i.e., Pediatric and child patients) has the DRL establishment priority. In addition, the DRLs should be revised periodically (e.g. every three or five years) (IAEA, 2001; Van˜o´ et al., 2017). DRLs value is a chosen dose quantity for a standard phantom or patient undergoing the same diagnostic procedure using different types of equipment (e.g. manufacturers or models). DRLs, for such radiation examination, are established as a 75th percentile over a distribution of selected quantities (e.g., CT dose index, administrated radiopharmaceutical and Entrance Surface Dose). DRLs quantities are collected from the same procedures, across all facilities, and then can be established nationally (Salama et al., 2017). Therefore, an enormous amount of teamwork is required to establish national DRLs for different diagnostic radiation procedures. This paper aims at providing an overview and evaluation of the current situation of the national DRLs in Saudi Arabia.

Materials and Methods

Overview of some international DRLs

In 1997, it became compulsory for member states of the European Union to apply for the patient radiation dose management in diagnostic radiology that was stated to be DRLs and defined as: "Dose levels for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment". These levels are expected not to be exceeded when a good and normal practice regarding diagnostic and technical performance is applied" (Wall, 2004). Figure 1 shows a comparison for DRLs established for abdominal computed tomography (CT) in some European countries (European Union, 2014). However, these differences are normal and accepted with regards to the following (Alessio et al., 2015):

- Methods used for setting DRLs procedures.
- Protocols and equipment were used to perform the procedure.
- Patient specifications.
- The experience of radiological staff and professionals.

Therefore, it is accepted that Saudi DRLs (SDRLs) are different from those established internationally. However, comparisons should be investigated to identify whether SDRLs are within the accepted range or if they are significantly different. These comparisons will establish whether further radiation protection optimization is required urgently or not. One of the earliest countries to establish national DRLs was the UK. The 75th percentiles (third quartiles) for radiographic examinations in 1980, 1995 and 2000 were compared and are shown in Table 1. Table 1 shows an improvement in optimization of patient radiation protection as a result of dose reduction in the UK (Wall, 2004). The average improvement was proximally 50% during these periods (1980, 1995 and 2000).

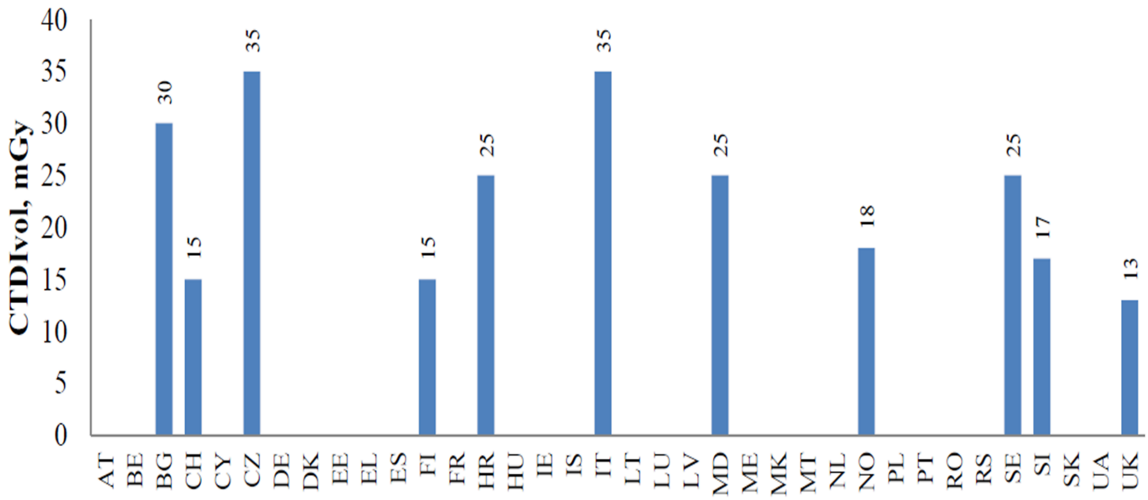

Fig. 1. DRL comparisons for abdominal CT in some European countries (European Union, 2014)

TABLE 1. The 75th percentiles or third quartiles for radiographic examination in 1980, 1995 and 2000 were compared [IAEA, 2001]

Radiograph or examination	Rounded third-quartile values		
	Mid-1980s Survey	1995 Review	2000 Review
	ESD per radiograph (mGy)		
Skull AP/PA	5	4	3
Skull LAT	3	2	1.6
Chest PA	0.3	0.2	0.2
Chest LAT	1.5	0.7	1
Thoracic spine AP	7	5	3.5
Thoracic spine LAT	20	16	10
Lumbar spine AP	10	7	6
Lumbar spine LAT	30	20	14
Lumbar spine LSJ	40	35	26
Abdomen AP	10	7	6
Pelvis AP	10	5	4
	DAP per examination (Gy cm^2)		
IVU	40	25	16
Barium meal	25	17	13
Barium enema	60	35	31

DRLs and radiation modalities

Computed tomography (CT)

DRLs for CT procedures are a well-studied field, and there is an abundance of published papers available. For example, the United States and also some European countries have established DRLs for many CT procedures (Tsapaki et al., 2006; Kanal et al., 2017). The reason for the extensive study of CT DRLs is the high radiation dose contribution of CT to the population from CT procedures, compared to other diagnostic modalities (Treier et al., 2010; Kanal et al., 2017; Appel et al., 2018). Establishing CT DRLs is performed using a 75th percentile of CT dose index (CTDi) and Dose length product (DLP) quantities distribution, for the same CT examination procedure and penitents parameters (i.e., weigh, height, age and gender) (Tsapaki et al., 2006).

Nuclear medicine

Nuclear medicine DRLs have been established as the 75th percentile of the administrated radiopharmaceutical distribution , for the same examination conditions (i.e. patient weight, height, gender, procedure) (Korpela et al., 2010). Optimization of administered radiopharmaceutical is necessary, particularly for pediatric patients (Fahey et al., 2017).

Dual or hybrid imaging (PET-CT and SPECT-CT)

Despite the significance of PET-CT and SPECT-CT, their procedures could include patient radiation doses that are higher than other modalities (i.e. routine CT, nuclear medicine and radiography), because of the combination of x-rays and radioactive materials (i.e. FDG PET-CT) (Andersson et al., 2015; Jallow et al., 2016). The procedures and purposes of routine CT is completely different from CT in hybrid imaging systems. Currently, there is little data published on CT DRLs in hybrid imaging systems, and most of the available data is mostly for routine CT (Jallow et al., 2016; Gardner et al., 2017; Lima et al., 2018). However, CT DRLs for some CT procedures in hybrid imaging systems have been established in some countries (e.g. the UK, Switzerland and the United States). Setting DRLs for diagnostic procedures in these modalities (regardless of PET-MRI) requires establishing an optimal activity (i.e. optimal administrated radiopharmaceuticals), as well as establishing CT DRLs quantities (Andersson et al., 2015; Lima et al., 2018).

X-ray guided procedures and fluoroscopy

Few Studies have been carried out in the DRLs for X-ray guided procedures and fluoroscopy. In general, DRLs for x-ray guided procedures are carried out in a single institution that is considered a limitation of existing studies (Vano et al., 2009; Leng, 2018). Complicity of setting DRLs for x-ray guided procedures is related to the large variations in patient radiation doses. Thus, patients and medical staff could be exposed to unusual radiation doses (Saukko et al., 2017; Kottou et al., 2018). In addition, complicity is related to patient positioning, exposure time, clinical indications and absence of standards, which could lead to additional radiation doses and high DRLs (White et al., 2013). However, less complicity was found in setting DRLs for fluoroscopic procedures (e.g. Barium Swallow) compared with other fluoroscopic guided procedures. To conclude, x-ray guided procedures could be the most complex modality to set DRLs among other diagnostic x-rays modalities. In addition, there is large variations in procedures and a lack of knowledge and, consequently, absence of DRLs results comparisons.

Dental radiography

Few countries have established dental DRLs that might be related to the low radiation dose of dental radiography compared with other diagnostic x-ray procedures. However, dental radiography is one of the most frequent diagnostic procedures (~ 25% of total diagnostic examinations), particularly the intraoral procedures. Dental radiography DRLs should be included in the national DRLs establishment plan, because of the high frequency uses (Alcaraz et al., 2016).

Mammography and tomosynthesis

Breast tissue radiosensitivity (i.e. tissue weighting factor, w_T) is categorized by ICRP Publication 60 to have a factor of 0.05, whereas the highest and the lowest are gonads and skin weighting factors of 0.2 and 0.01, respectively (Cember & Johnson, 2009). Digital breast tomosynthesis has a cancer risk of one to two times more than routine mammography (Hendrick & Edward, 2010). The methodology of the establishment of mammography DRLs was found to be significantly different among countries, including protocols, used conversion factors and used percentile values. Thus, international DRLs comparisons were found to be difficult (Suleiman et al., 2015). To overcome these variations and allow comparisons, it was suggested that DRLs should be correlated to the thickness of the compressed breast and equipment specifications (Suleiman et al., 2017).

DRLs data selection

With regard to DRLs data selection, the question to ask is "What are the purposes of categorizing patients into groups and what are the rules of this category?". The patients are divided into groups as follows: Patient's age, gender and size.

Patient's age and DRLs

Pediatric and child patient ages can be divided into: <1 year, 1 year <5 year, 5 year <10 year and 10 year <16 year) (Rehani, 2015). Fig. 2 shows the relationship between patient age and weight and skull dimension (Huda et al., 2004).

The plots at the left-hand side of the Fig. 2 shows a rapid increase in patient weight during the first several years. The weight and age correlation are observed during the first 20 years of the patient's life, whereas this correlation does not exist during the rest of the patient's life. The plots at the right-hand side of the Fig. 2 shows a rapid increase in patient head size until two years old; this increase is then modest until 18 years. Thus, regarding patient weight, patients in the youngest age group – <18 – should be divided into groups with a narrow interval, whereas for adults who are >18, the size intervals can be larger.

Patient's gender and DRLs

Females' body habitus is different from males, and this may result in differences in DRLs between genders. For example, females' heads are approximately 5% smaller than males; thus, the difference in entrance radiation dose for intraoral examination is found to be 5% between males and females (Huda et al., 2004; Izawa et al., 2017). However, there are no studies found on the establishment of DRLs using groups divided by gender, except a few studies on the establishment of DRLs for head procedures (Wall, 2004).

Patient's size and DLRs

The required radiation dose to produce acceptable or good image quality is significantly dependent on the patient size (weight, height and habitus) (Wall, 2004). However, good image quality does not have specific standards; it depends on the health professional practitioner decisions (e.g. radiologists, radio-technologists and physicists). For example, image quality could be sufficient to diagnose one pathology and insufficient to diagnose others (Vock & Frija., 2016). Weight intervals can be 10 kg for adults (e.g. 40–50, 50–60, 60–70) and 5 kg for children, whereas height intervals can be 5 cm for adult patients. For adult head procedures, lateral thickness is required (Kanal et al., 2017). In a study performed to establish DRLs for some CT procedures, the variations in adult DRLs quantities for head, neck, chest and abdomen were approximately 7%, 27%, 58% and 72%, respectively (Kanal et al., 2017). These results show the importance of dividing patients into groups regarding the parameter size – especially for chest and abdomen procedures.

Methodologies of collection DRLs values

Patient-based values

Patient dose monitoring systems are an important tool in modern CT for the purpose of quality assurance (Bethge et al., 2018). DRLs CTDi and DLP quantities are recorded in the dose profile and are used for CT DRLs establishment. This method is recommended and efficient to be compared with other methodologies (Pyfferoen et al., 2017). However, tools to verify or calibrate the collected values could be required (Corona et al., 2015); for example, using solid-state or ionization-chamber detectors and comparing the results with the patient dose profile (Corona et al., 2015). Patient-based methods to collect DRLs values, among diffident radiation modalities, provide realistic measurement conditions (Suleiman et al., 2015).

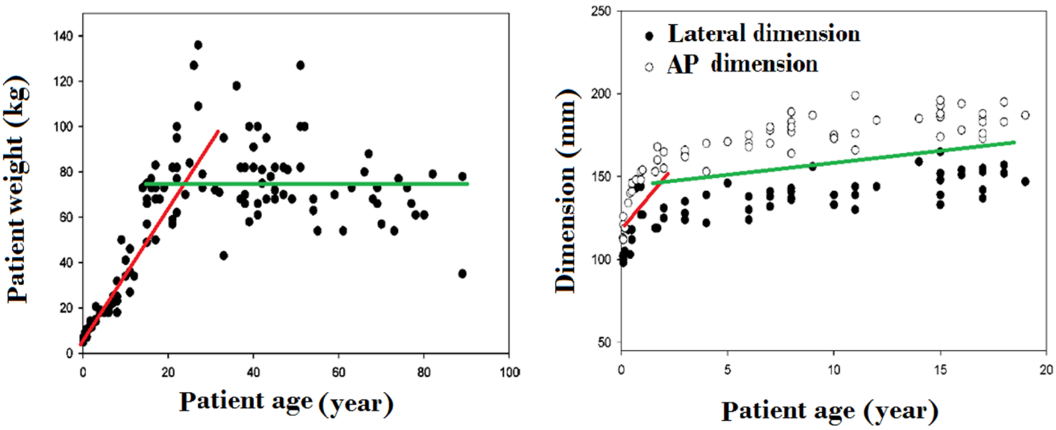

Fig. 2. Relationships between patients' age and weight and skull dimensions (Huda et al., 2004)

Phantom-based values

Phantom-based values is a method for evaluation of organ dose conversion coefficient in occupational, medical and environmental radiation protection. DRLs quantity measurements using phantoms are not typically the same as in the clinical environment (Suleiman et al., 2017). This is due to the limitations in variability of real patients' sizes using imaging protocols. However, phantoms have been used to assess doses and to establish DRLs; for example, head and body phantoms (cylindrical polymethyl-methacrylate phantoms) with pencil ionization chambers (Hatziioannou et al., 2003). The phantoms were provided with holes (e.g. 1cm under the phantom surface), to enable DRLs quantity to be measured. It is recommended to use anthropomorphic phantoms small 3D volume elements that describe the anatomy, and specify the density of different organs and tissues of the human body. Furthermore, it is recommended that the use of phantoms-based values as the first step to set up a more complete system that is relayed on patient-based values. In comparison with the patient-based measurement, this method is less time-consuming, and fewer exposures are required for each facility (Vassileva & Rehani, 2015).

Results and Discussion

The importance of establishing national DRLs

Variations in patient radiation doses, for the same diagnostic procedure at different facilities, were reported to be of factor >3, (Wall, 2004) (European Union, 2014). In another study, the variations were reported to be of factor >20 (Dabin et al., 2014). Thus, these studies verified that establishing national DRLs is a necessary task to optimize patient doses and urgent actions should be taken if these levels are exceeded. Data should be collected from different radiation imaging facilities within a country, so that national DRLs can be established (Rehani, 2015). Data is provided from a wide national survey of a radiation dose for a defined diagnostic x-ray procedure. The national DRLs are then selected at the 75th percentile value over the distribution of the collected data. Diagnostic procedures and equipment are different between different facilities in the same country, as well as between countries (Vassileva & Rehani, 2015). Therefore, one country's national DRLs are not capable for another country (Johnston & Brennan, 2000; Rehani, 2015). Figure 3 shows a defined DRL at the 75th percentile (3rd quartile) on the dose distribution curve.

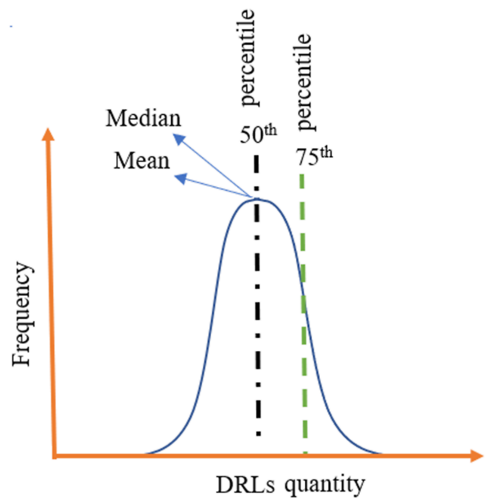

Fig. 3. A sketch of defined DRLs quantity; the 75th percentile is the green dashed line and the median, mean or 50th percentile is the black dashed line

The Fig. 3 shows that the median, mean and 50th percentile are the same. However, the median and the mean are not always the same, unless the distribution curve has a gaussian shape (i.e. a symmetrical or normal shape) as it appears in the Fig. 3 (Sarkar & Rashid, 2016). Periodically, the DRLs should be evaluated and updated (e.g. every three or five years) or when new imaging technology or procedures are introduced (Vañó et al., 2017). Accordingly, DRLs in different facilities should be monitored so that radiation protection can be optimized**.**

Suggested SDRLs for some procedures

Few studies on the establishment of SDRLs were found, whereas there was an abundance of Saudi studies on radiation dosimetry. However, more studies on SDRLs may be in preparation for publishing (i.e. until December 2020). Furthermore, studies on radiation dosimetry can be utilized for the establishment of SDRLs. This can be achieved if these studies suit the DRLs establishment criteria. Examples for this are the obtained dosimetry quantity, the used dosimetry method and the data availability (e.g. the equipment and protocols used and patient parameters). The following are three published studies on SDRLs and one study was carried out on radiation dosimetry, which could be utilized for the establishment of SDRL.

Qurashi et al. (2015) was carried out to set DRLs for some CT procedures. The study contains useful information, and few limitations were noticed. Data were collected from 14 sites in the western region of Saudi Arabia, then DRLs for five CT procedures were proposed and compared with some European DRLs for the same procedures. DRLs were proposed for a patient with a mean weight of 70 kg ± 10 kg; this could be one of the reasons behind the variation found in DRLs values, in addition to the reasons mentioned in the report. The collected data was not large, however it was sufficient to initiate DRLs for specific diagnostic procedures. Thus, more studies should be undertaken in other regions of Saudi Arabia and comparisons should be made, so that the SDRLs regarding these procedures can be established nationally. However, to establish SDRLs for specific procedure in different sites, studies should be carried out under the same measurement conditions. Therefore, collaboration between researchers is necessary, as individual work could lead to incomparable DRLs results.

In March 2018, SDRLs were suggested for CT guided procedures (Cardiac Computed Tomography Angiography (CCTA)) (Alhailiy et al., 2018). Alhailiy et al. (2018) aimed to set SDRLs for a CCTA procedure; this procedure is used to diagnose patients with cardiovascular diseases. The average patient age and weight were reported to be 48 years (39–56 years) and 77kg (68–87 kg) respectively. It is important to set SDRLs for all diagnostic procedures, however, the procedure frequency, radiosensitivity, life expectancy and patient group selection should be taken into considerations. Though these studies represented a valuable effort to propose SDRLs for some diagnostic procedures, the priorities for establishing SDRL procedures were not considered. The reasons for this could be availability of research tools, time and place, access to institutions, researcher interests, and others.

In December 2020, the Saudi Food and Drug Authority (SFDA) had established a national DRLs for some CT examinations (Food, Saudi, Drug Authority, and Medical Devices Sector, 2020). It was stated that "This study is the first governmental initiative DRLs in the Kingdom of Saudi Arabia (KSA) by the SFDA to establish National Diagnostic Reference Levels". Although The study is novel and contains useful information, more detailed CT procedures, in addition to patients parameters, are recommended in future studies.

Thus, approximately >90% of SDRLs for diagnostic radiation procedures have not been covered. Therefore, more studies need to be carried out, which could be accomplished within a few years. The task could be accelerated significantly by encouraging the relevant facilities (e.g. Saudi Universities and research centers) to participate in this work, through researches, projects and theses on SDRLs subjects and radiation dosimetry.

Regarding radiation dosimetry studies, there are many published papers, yet they do not adequately cover all the SDRLs subjects (Abdelhalim, 2010; Sulieman et al., 2018). Moreover, some of the studies could be not capable for establishing DRLs. It is recommended that the radiation dosimetry studies that can be used in the establishment of DRLs need to meet the following criteria:

1. The selected radiation dose values should be capable, or able to be converted into DRLs quantities.
2. The patient and equipment parameters should be available.
3. The sample size should be adequate and distributed among different facilities.
4. The measurements should be considered under the same conditions.
5. The dose assessment method should be accurate and efficient.

Regarding the criteria mentioned above, for example, the quantity used to assess the radiation dose for pediatric patients undergoing abdominal radiography is the Entrance Surface Dose (ESD) (Alqahtani, 2017). This quantity was recommended by ICRP for setting DRLs. In addition, the patient groups were identified in terms of age and weight. The sample size was enough to set DRLs and the equipment specification was identified. In this study, dose calculation software and collected data (i.e. exposure and anthropometric data) was used to measure the dose. This measurement could be classified under the method of patient-based dosimetry, which is more accurate than phantom-based dosimetry. In addition the report stated that "the results are useful to establish diagnostic reference levels (DRLs)". However, the value used to quantify the dose was the median (the 50th percentile), whereas the 75th percentile is recommended for DRLs establishment. Furthermore, the data was collected from two sites and it is recommended that the data has a large distribution; this is to reflect the realistic DRLs established value among institutions. Nevertheless, the data and results appeared to be useful, as well as other calculated values (e.g. the 75th percentile and dose distribution chart) and the original data may be provided by the researcher.

To conclude, few studies on SDRLs have been carried out, whereas there are many studies on radiation dosimetry. Radiation dosimetry can be utilized in the establishment of SDRLs, if they are valid regarding definite criteria. However, approximately >90% of SDRLs for diagnostic radiation procedures have not been set.

Priorities in SDRLs establishment

The radiation doses from abdominal and chest CT examinations were found to be 10 and 100 times more than that of conventional examinations, respectively (Treier et al., 2010). It was reported that medical exposures in the United States and similarly in many countries (e.g. Switzerland) (Treier et al., 2010), were mainly from CT (~50% of the total) and nuclear medicine (~25% of the total) examinations (Mahesh, 2009). Therefore, CT and nuclear medicine procedures could be a main concern in medical exposure. Because infants are smaller in size, the estimated effective radiation dose for infants is four times higher than for adult patients (Huda et al., 2004). Furthermore, the Committee on Biological Effects of Ionizing Radiation (BEIR) reported that radiation-induced cancers for children could be three times higher than for adults (Fahey et al., 2017). Even though it is important for DRLs to be established in Saudi Arabia for the most frequent procedures, DRLs for pediatrics procedures have priority because of their high radiosensitivity and long-life expectancy. Figure 4 shows the relationship between patient age and estimated cancer risk from low radiation dose in routine head and abdominal CTs (Brenner et al., 2001).

The Fig. 4 shows significant differences in the estimated cancer risk between children and adults. Moreover, it was reported that the total cancer risk from routine abdominal CT for young females <20 years was double that of the young males; this is because of the additional risk of breast cancer. CT, nuclear medicine and x-rays guided procedures were reported to have the highest radiation doses among diagnostic procedures (Schauer & Linton, 2009; Roch & Aubert, 2013; Pyfferoen et al., 2017). Table 2 shows a comparison between radiation doses for general radiography, nuclear medicine, CT and x-ray guided procedures (Lin et al., 2010).

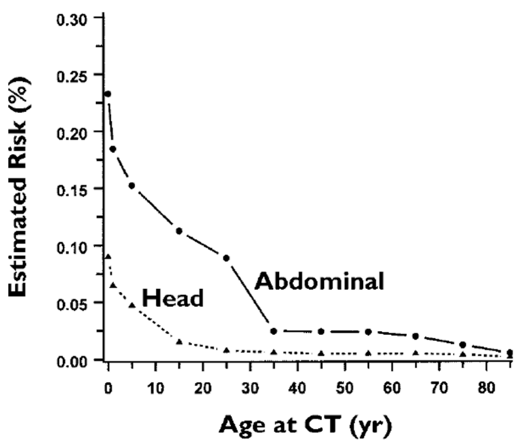

Fig. 4. Relationship between estimated cancer risk from low radiation dose routine head and abdominal CTs, and patient age (Brenner et al., 2001)

Table 2 shows that the highest radiation doses are from CT procedures, fluoroscopic guided procedures and nuclear medicine, respectively, whereas the lowest are from radiography and mammography.

TABLE 2. Comparison between radiation doses for general radiography, nuclear medicine, CT and x-ray guided procedures (Lin et al., 2010)

Examination	Radiation dose (mSv)
Computed tomography	
• Sinuses	0.6
• Head	2.0
• chest	7.0
• Chest (Pulmonary embolism)	10.0
• Abdomen and pelvis	10.0
• Multiphase abdomen and pelvis	31.0
Radiography	
• Extremity	0.001
• Chest	0.1
• Lumber spine	0.7
• Abdomen	1.2
Other	
• Mammography	0.7
• Bone densitometry (DEXA)	0.001
Nuclear Medicine	
• Lung ventilation/ perfusion	2.0
• Bone scan	4.2
• Cardiac perfusion (sestamibi)	12.5
Fluoroscopy	
• Barium swallow	1.5
• Coronary angiography	5-15

Conclusion

An enormous amount of work is required to establish SDRLs for different diagnostic radiation procedures, as approximately >90% of SDRLs are not established or published. Collaboration between researchers is necessary to allow comparisons of DRLs results and establish national DRLs. Furthermore, DRLs for pediatric procedures should be a priority.

Suggestions and recommendations, based on the international recommendations

Suggested procedures to establish SDRLs

Work should begin with healthcare centers that have the highest workloads and those procedures that are conducted most frequently and have highest radiation dose (to initiate DRLs, patient data ≥10 is sufficient, for same patient groups and procedures) (Zira et al., 2017). In addition, DRLs for pediatric patients is a priority, because of their high radiosensitivity and long-life expectancy (Dabin et al., 2014).

Selecting the appropriate method for DRLs data collection (i.e. patient-based or phantom-based data collection).

Collecting DRLs data and divide the data into groups with the same conditions (e.g. procedure, age, weight and gender). However, for adult DRLs, standard-size patients can be used, whereas for pediatric patients, age grouping is essential.

For pediatric patients, the diagnostic radiological protocol should be age-based (e.g. neonate, 6 months–1 year, 1 year–2 years) (Bibbo et al., 2016). Adult patient size parameters (height and weight) should be recorded where possible.

Pediatric patient size and age parameters should be included in the exam protocol. For example, pediatric protocols can be categorized into age-based and weight-based for head and other body parts respectively (Bibbo et al., 2016).

Collecting data from different sites; thus, the data reflects the real value for local, regional (sub-county) or national DRLs.

Analyzing DRLs data and set the required values, e.g. the 75th, 50th and 25th percentiles.

Establishing local, regional or national DRLs for the study's specific procedure.

Finding facilities where DRLs exceed the 75th or 50th percentiles, so that an investigation can be carried out to determine the causes.

Comparing the established DRLs with the international DRLs and examining the reasons for any differences, if there is any.

Recommendations

The following are suggested points and recommendations to initiate the establishment of SDRLs:

1. Identifying teams in charge of collating data from Saudi Arabia cities or regions and for setting DRLs.

2. If the data provided is limited, the DRLs can be initiated and later revised when enough data is available.

3. Setting DRLs for pediatric procedures should be a priority.

For more radiation protection optimization, the 50^{th} percentile can be targeted (i.e. achievable doses (ADs)) (Alessio e al., 2015; Kanal et al. 2017).

4. Internationally, it has been recognized that interventional diagnostic procedures include a high risk of radiation dose to patients and staff, with complicity in dose assessment and DRLs setting. Thus, a special focus on interventional procedures could be an important issue, in terms of DRLs setting, procedures revision, dose assessment for patients and medical staff.

Collecting Data from the same examination procedures, but using different imagining modalities (e.g. SPECT/CT and PET/CT) should have different DRLs (Vañó et al., 2017).

Encouraging the Saudi universities and research centers to participate in this work; this could significantly accelerate the establishment of SDRLs for many diagnostic procedures.

Collaboration between researchers is necessary, as individual work could lead to incomparable DRLs result, consequently; these results integration is invalid and cannot be used to establish national DRLs.

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Ethical Approval statement: As there are no humans recruited for this review study, and the analysis is based on the data that was published in the literature by other studies, ethical approval of this study was waived.

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